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MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

A Thought Inspired by the Coming Machine-Tool Exhibitions

Of the forty-six Presidents of the A.S.M.E. the following have played important roles in the development of the machine-tool industry:

JOHN E. SWEET	AMBROSE SWASEY
COLEMAN SELLERS	FREDERICK W. TAYLOR
OBERLIN SMITH	JAMES HARTNESS
CHARLES E. BILLINGS	FRED J. MILLER
WORCESTER R. WARNER	DEXTER S. KIMBALL

(See editorial on Presidents of the A.S.M.E. and The Master Tools of Industry in this issue)

SEPTEMBER 1927

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Leak-proof tanks and pressure vessels—by oxwelding*

ALL riveted storage tanks and pressure vessels develop leaks ultimately. Every year thousands and thousands of dollars' worth of volatile liquids evaporate from storage vessels even though the riveted vessels may appear tight when tested. Oxwelded vessels on the other hand are actually and permanently leak-proof.

That is why oxwelded tanks and pressure vessels have become popular.

A test was made recently on a welded tank five feet in diameter and forty-three feet long, made of inch and one-eighth steel with double-vee oxwelded joints. The vessel was designed on the basis of a fibre stress of 8,000 lb. per sq. in., but when the test pressure was raised to 1,000 lb., the testers were applying a pressure equal to three times the working pressure (based on a design fibre stress of 9,000 lb. per sq. in.). Two tests at this pressure showed practically no distortion except around the manhole. It was then tested to destruction, and failed through the manhole. Examination proved that the welds were in no way affected.

It would be impossible to make such a high proof test on riveted pressure vessels because the riveted seams spring leaks long before the walls or the heads are severely stressed. But it is now possible to test even the head construction and design, since oxwelded joints and seams are as strong as the metal walls themselves.

Linde Procedure Controls explain in detail the construction of pressure vessels with Oxweld No. 1 High Test rod.

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LINDE OXYGEN

★ No. 9 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

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Lybrand Smith

MECHANICAL ENGINEERING

Volume 49 September, 1927 No. 9

Accidents and Production

Summary of a Report of an Investigation by American Engineering Council

By L. W. WALLACE,[1] WASHINGTON, D. C.

EARLY in 1926, American Engineering Council appointed a special committee to make an engineering and statistical assay of the comparative relationship between industrial accidents and production. Council undertook the study upon the request of the National Bureau of Casualty and Surety Underwriters, which provided the necessary funds for its execution. A satisfactory program was soon developed and a working organization set up at Council Headquarters in Washington. During 1926, information nationwide in scope and broadly representative of existing conditions was secured, from which a forcible report has been prepared which will be issued by Harper and Brothers about October 1.

The primary objective of the study was to prove or disprove the common belief that a safe factory is an efficient factory, and that an efficient factory is a safe factory. The Committee has accumulated sufficient evidence to indicate, beyond the possibility of doubt, that this premise is correct. Since such relationship between accidents and production is an established fact, there must be some controlling influence which has brought it about. The simultaneous improvement in both the production and safety activities of industrial establishments is unquestionably the result of better management—a more effective executive direction and control. Consequently the reduction of accidents is just as much a responsibility of the major executives of industry as is the increasing of productivity.

It should be pointed out that no effort was made to determine the direct causal relationship between the factors which influence accident and production rates. It would be practically impossible to do so, because an improvement in productivity is due to a multiplicity of factors, many of which also affect the accident rates. Likewise it will be readily conceded that the converse is true.

Because of the extent and scope of the data secured, the Committee believes its findings are applicable to industry in general. Information was secured from about 14,000 companies, with an aggregate experience of 122,000 company-years. These companies had, in 1925, approximately two and one-half million employees, or one-fourth of the industrial workers of the country. This is equivalent to over eighteen million man-years, or over fifty billion man-hours.

Findings of the Committee

Most significant results have been obtained from a comparative analysis of the accident and production performances of this large cross-section of industry. Although the findings of the Committee have not yet been completely drafted, the following brief statements may be given as indicative of the results.

In the first place, the experience of a representative group of plants clearly indicates a fundamental of management, namely: Maximum productivity is dependent upon the reduction of accidents to an irreducible minimum.

There is conclusive evidence that in the well-managed industries, over the period of years studied, marked increases in productivity occurred simultaneously with equally marked reductions in the frequency and severity of accidents.

The rate of production per man-hour for the industries studied was 14 per cent higher in 1925 than in 1922.

The rate of accident frequency per man-hour for the industries studied was 10 per cent lower in 1925 than in 1922.

The rate of accident severity per man-hour for the industries studied was 3 per cent higher in 1925 than in 1922.

The net experience of the individual groups studied was that 80 per cent had increases in the rates of production; 52 per cent had decreases in the accident-frequency rate; and 68 per cent had decreases in the accident-severity rate.

The initial or accompanying cost of industrial accidents is an appreciable loss in the operation of industry, probably very much greater than is commonly believed.

Minor accidents are accountable for a much larger amount of productive time and value lost than is generally recognized.

Effective organized safety work, which is reducing the frequency and severity of accidents, is being carried out in a relatively small percentage of industrial plants.

Industrial executives have not given to accident prevention that degree of executive attention and direction which its economic and humanitarian significance warrants.

The accident and production performance of the best plants in each industry clearly shows that tremendous improvements can be achieved by the remaining plants in each industry.

The majority of industrial group experiences indicate that a comparatively slight improvement in production and accident rates will change undesirable to desirable records.

It is impossible either to prove or to disprove the thesis that there has been an increase in the number and severity of accidents occurring in industry as a whole during the past few years.

Analyses of Selected Groups of Industries

The accident and production performance of twenty major industries and over 120 product groups will be presented in the published report. The facts disclosed by a careful analysis of some specific industrial groups follow.

Cement. One hundred and twenty cement companies, with approximately 35,000 employees and manufacturing 90 per cent of the output of the United States, experienced an increase of 32 per cent in the rate of production from 1920 to 1925, a simultaneous decrease of 29 per cent in the accident-frequency rate, and a 30 per cent decrease in the severity rate.

Chemical. The chemical industry, from 1921 to 1925, had a marked increase in the rate of production. This accomplishment was attended with a reduction in the accident-frequency rate, which declined faster than the production rate increased. A large reduction occurred in the severity rate in some of the product groups of the industry.

Coal Mining. The production rate of the anthracite coal-mining industry, represented by 337 companies with 160,000 employees, declined 4 per cent from 1916 to 1925. This was accompanied by a decrease of 9 per cent in the accident-fatality rate.

The production rate, for 71 per cent of the bituminous coal-mining industry, increased 30 per cent from 1916 to 1925. During the same period the accident-fatality rate increased 39 per cent.

Coke. The accident and production performance of from 75 to 80 per cent of the total tonnage of the coke industry manufacturing by the by-product process, has shown a continuous improvement during the nine-year period from 1916 to 1924. An increase of 107 per cent in the rate of production has been accompanied by

[1] Executive Secretary, American Engineering Council. Mem. A.S.M.E. Contributed by the Management Division and presented at the Spring Meeting, White Sulphur Springs, W. Va., May 23 to 26, 1927, of The American Society of Mechanical Engineers.

a reduction of 75 per cent in the accident-frequency rate, and a reduction of 37 per cent in the severity rate.

The beehive-coke industry, represented by 99 companies, with 6450 employees, had an increase of 47 per cent in the rate of production from 1916 to 1924, an increase of 9 per cent in the accident-frequency rate, and an increase of 27 per cent in the severity rate.

Electric Light and Power. The electric light and power industry, in general, is making but slight increase in the rate of production expressed in kilowatt-hours generated per man-hour. The combined production rate of 25 companies, with 24,092 employees, increased only 2 per cent, from 1921 to 1925; the accident-frequency rate decreased 3 per cent; and the severity rate decreased 22 per cent.

Electric Railways. Apparently little change is taking place in the production rate of the electric-railway industry. However, from 1920 to 1925 the accident frequency rate decreased 39 per cent.

Gas. The combined experience of seven gas companies with 2278 employees shows a decrease of 8 per cent in the production rate, from 1921 to 1925, a decrease of 24 per cent in the accident-frequency rate, and a decrease of 61 per cent in the severity rate.

Iron and Steel. It is evident that in general an increase in the rate of production for the iron and steel industry has been accompanied by a remarkable reduction in the accident-frequency and severity rates.

Machine Building and Metal Working. The accident and production performance of the plants studied in the machine-building and metal-working industry was not uniform. In most divisions there occurred a considerable improvement in productivity. In some divisions this was accompanied by decreases in the frequency and severity of accidents, while in other cases increases took place. The non-ferrous plants in the industry experienced a consistent and substantial improvement in productivity, and a marked unfavorable accident performance.

Mineral Mining. The mineral-mining industry, represented by 2783 companies with 123,128 employees, experienced an increase of 50 per cent in the rate of production from 1916 to 1924. This was accompanied by an increase of 14 per cent in the accident-frequency rate, and a decrease of 17 per cent in the severity rate.

Paper and Pulp. The analysis of the data received from fifteen plants in the paper and pulp industry shows as favorable and as uniform a performance in accidents and production as that of any industry studied. The rate of production has been steadily increased 19 per cent during the five-year period from 1921 to 1925, while simultaneously the accident-frequency rate has been reduced 18 per cent, and the severity rate has been reduced 31 per cent.

Quarry. The quarry industry, from 1916 to 1924, made but slight improvement in its accident and production performance. There was an overall increase of 12 per cent in the rate of production for 1660 quarries, accompanied by an increase of 3 per cent in the accident-frequency rate, and a decrease of 13 per cent in the severity rate.

Steam Railways. Upward trends in the rate of production and downward trends in both accident-frequency and fatality rates have been the experience of steam railways during the past ten years. The analysis covered the experience of 176 companies, operating 90 per cent of the total mileage of the United States. The trend curves for both the freight and passenger service of the industry show that the general upward trend for production and downward trend for accident rates has been the situation not only for the longer ten-year period but also for each year. The comparison of the accident rates by crew groups gives positive evidence that the accident-prevention measures applied by the roads have not been confined to any one group, but that all employees are encompassed in programs of safety.

Telephone and Telegraph. From 1922 to 1925 a reduction of 62 per cent in the accident-frequency rate occurred among 82,000 males in the plant forces of the telephone and telegraph industry. This was accompanied by an increase of 26 per cent in the rate of production.

Textile. That portion of the textile industry surveyed shows almost invariably an unfavorable accident and production performance. Decreases in the rates of production are generally accompanied by increases in both accident-frequency and severity rates, the increases in the severity rates being very marked. Numerous mills visited were unable to supply data because of the lack of records, which is presumably an indication of no organized safety activities.

Woodworking. The experience of plants in the woodworking industry is generally favorable in productivity but unfavorable in accidents. During the past few years substantial increases have been made in the rate of production by most groups and individual companies. This performance has been accompanied by marked increases in either the accident-frequency or severity rate.

Discussion

LUTHER D. BURLINGAME[2] wrote that the paper showed evidence of extensive research and the accumulation of a great mass of statistics relative to accidents in industry, which should be of material value when completed.

At least two important uses of such statistics were:

1 (*a*) To learn the facts regarding the nature and extent of accidents, in order that steps might be taken at the strategic points toward their prevention
(*b*) To use such statistics as a basis for legislation looking to that same end
(*c*) To determine the burden to industry, including both the loss to the manufacturer and to his employees, caused by accidents.

2 The use of statistics as a basis for competition so that "the spirit of the game" and of rivalry might be added to other influences combining to prevent accidents. This could be in the form of competition between (*a*) allied industries, (*b*) separate factories, or departments under a single management, and (*c*) competition with past records in the factory itself, in an endeavor to improve the standing over former records.

Activities were being carried on by the Providence Safety Council not only in accumulating statistics and using them for the purpose given under 1, but also in stimulating competition between different local industries, grouped together in such a way as to have somewhat common hazards, with the purpose of keeping the thought of accident prevention constantly in the minds of both the manufacturer and employees. This was done by means of an annual competition for a bronze trophy, offered by Senator Jesse H. Metcalf of Rhode Island, as a prize for the manufactory making the greatest improvement over previous records.

There were now 84 organizations in Providence and vicinity competing for this trophy, and making a report each month as to their accident record, based on the standard statistical methods of the National Safety Council. These were divided into nine groups and represented more than 30,000 employees entered in the competition. This summary was issued as a monthly report, together with a report giving industrial accidents in the plant competing.

The Statistics Committee of the Providence Safety Council also made a monthly report analyzing the statistics for local public, home, and industrial accidents, giving the number of accidents, deaths, amount of property damage, with a separate analysis for automobile accidents, separating accidents to children and adults; accidents in the congested area, whether to pedestrians or riders, also an analysis of circumstances attending the occurrence of accidents whether caused when turning a corner, skidding, passing on curve or hill, etc., the condition of the pedestrian, whether or not intoxicated, sex of pedestrian, condition of road, weather conditions, lights, location, etc.

The same plan was also followed in reporting home accidents, which were divided under such headings as asphyxiation, burns, drownings, falls, poisons, etc.

In addition to this community activity in compiling and using accident statistics, such statistics had been carefully kept at the works of the Brown & Sharpe Mfg. Co., for many years. A feature of their use was a competition in accident prevention between departments. In order to equalize conditions in this competition a handicap was allowed for each department in proportion to its hazards. With this handicap as a basis the rating of departments

[2] Industrial Superintendent, Brown & Sharpe Mfg. Co. Mem. A.S.M.E.

was figured each month and they were classed as "excellent," "good," "bad," or "very bad," according to their rating. A report was posted on the bulletin boards, arranging all departments in order as they stood by their average rating, for the month. At the close of each year, an annual report was made which contained not only the record for the past year but also the standing of the department during the entire period in which there had been competition, which now covered thirteen years.

While no prizes were offered in connection with this competition, department foremen and employees were impressed with the fact that this record would "stare them in the face" for years to come and it was constantly held up to all departments to endeavor to bring their standing up toward the top of the list in the "excellent" class. The report showed that for the year 1926 some departments which had at some time passed through a period having a record of "very bad" were in more recent years rated "excellent" but were still near the bottom of the list because of their past bad record.

S. H. Libby[3] said that the effect of accidents, in so far as production was concerned, would vary with the character of the plant where the accident happened. While there would be an immediate effect with hourly rate workers, with piece workers there would be practically no change in production.

He did not feel that the increase in his company's production since 1920–21 was the direct result of no-accident campaigns. Since 1920–21 much of the inferior labor had been weeded out. Also new machine tools and new methods had increased production. Safety had, of course, some effect on the increase. Safety campaigns brought about "good-housekeeping" campaigns, and good housekeeping in a shop tended to safety.

Mr. Libby further said that while there had been a reduction in the number of accidents, the severity had remained about the same. These accidents were not due to lack of safeguards; in 33 accidents carelessness of the individual had caused 30, carelessness of others had caused 2, and the other had been laid to the company because of the complications surrounding it. Accidents came to skilled operators in operations done almost automatically and where there was a relaxation of vigilance.

Harold V. Coes[4] said that his company's severe accidents could not be traced to company or management negligence. It was impossible, he said, to train workers to take care of such apparently minor accidents as slivers of copper in their fingers, although many of these accidents resulted in blood poisoning. The women employees in particular could not be taught to wear goggles to save their eyes from bits of fine copper wire flying about.

Robert T. Kent[5] also spoke of the difficulty of getting employees to recognize the importance and value of safety measures. He cited an experience in a paper-box shop where the guards were removed by the operators. Every time an accident occurred, the guards would be temporarily replaced, but only for a few weeks. The impression had been gained by the workers that the guards interfered with production. It was subsequently brought out in the discussion by C. F. Lauer,[6] chairman of the session, that the piece rates had been adjusted to meet the new conditions brought about by the installation of the guards. Mr. Kent felt that such experiences as this showed the need for considering the psychological aspects of accident prevention.

F. R. Zimmermann[7] gave additional testimony of careful workmen who were injured by removing safeguards which had been installed for the prevention of accidents.

Mr. Libby said that his plant was run under a so-called industrial-relations plan. A coöperative committee and elected delegates from the shop had discussed the question of safety and safeguards for machinery, and they had established the rule that any one removing or tampering with a safety appliance should be immediately discharged.

Mr. Coes said that he was experimenting with a group bonus plan to prevent accidents, and found that many difficulties ironed themselves out, because if members of a group found that a careless operator was costing it money, they would find their own methods of dealing with him.

C. K. Tripp[8] said that new apprentices in his department were required to read aloud a list of all accidents that had occurred during the past twenty-five years. Also a suggestion plan was employed to help the boys to think about safety. They were troubled with many accidents to eyes, due to cinders blown into the shop windows from the smoke stacks.

J. H. Maguire[9] said that in his shop it was customary to invite a man who had suffered several accidents to find a new job, on the theory that he was a misfit. Time was given for the man to find a new job. Prizes for records of no lost-time accidents were also offered. Men who refused to wear goggles when goggles were necessary were discharged.

Chairman Lauer spoke of his studies on the Industrial Relations Committee of the Philadelphia Chamber of Commerce. The committee had found that besides statistics and theory and technical details there was a spiritual element which expressed itself in the altruism of the "Golden Rule." He did not know how to handle employees who would not coöperate with the management's safety precautions except by the exercise of patience. The spirit in which such workers were approached was important; as Mr. Maguire had said, many of them would find that they did not belong in a group working on such a basis and would go elsewhere.

Mr. Kent recalled Barth and Merrick's studies on the relation of fatigue to production. In many plants with which he had been connected machinery had been absolutely shut down for a definite period twice, and in one case three times, in the morning and afternoon work periods. The result was an increase in production. Although statistics on the relation between accidents and rest periods were not available, he felt that they would have shown that accidents which had occurred at certain hours were caused by fatigue.

J. E. Hannum,[10] who presented the paper in the absence of the author, closed the discussion by referring to some features of the report.

[3] General Electric Co., Bloomfield, N. J. Mem. A.S.M.E.
[4] General Manager, Belden Mfg. Co., Chicago, Ill. Mem. A.S.M.E.
[5] Bridgeport Brass Co., Bridgeport, Conn. Mem. A.S.M.E.
[6] Treasurer, General Manager, Day & Zimmermann, Inc., Philadelphia, Pa. Mem. A.S.M.E.
[7] Chicago, Ill. Mem. A.S.M.E.
[8] Lynn, Mass.
[9] Haynes Stellite Co., Kokomo, Ind. Mem. A.S.M.E.
[10] Washington, D. C. Assoc-Mem. A.S.M.E.

Preventing Eye Injuries in the Shop

INDUSTRIAL executives, superintendents, and foremen should coöperate in enforcing definite rules which will compel workmen to wear eye protectors on all jobs that are likely to present eye injury hazards.

In many factories employees may be seen using old matches, toothpicks, soiled pocket handkerchiefs, etc., for removing particles from the eyes of their fellow-workers. In some cases the particle actually penetrates the coat of the eyeball, and unless it is properly removed, especially if it is a particle of metal, the sight of both eyes is in danger through sympathetic inflammation which may cause blindness.

Efficient eye protectors should be worn by workmen when grinding, buffing, handling molten metal, babbitting, chipping, riveting, drilling, welding, handling acids or dangerous chemicals, and all other operations that endanger the eyes. Forging machines and drop hammers also add to the hazards. Hot saws send large showers of sparks in all directions, which may cause serious injury to the eyes. Many workmen have lost the sight of an eye by being struck with a bit of steel broken from the head of a cold chisel, set punch, or other tool.

With proper eye protection, production will actually be increased on many jobs, since the workman can work faster when he does not have to be constantly guarding his eyes against chips, dust, or flying scale.

The goggles or eye protectors selected should be adapted for the particular work handled. They should be as light as possible and have suitable side protectors. The metal parts should be rust-proof and easily adjusted, by bending, to conform to the shape of the face. Let us keep in mind the fact that the proper use of suitable safety goggles has proved the most effective means of protecting the eyesight of workmen in large industrial plants.—A. Eyles in *Machinery*, August, 1927, p. 932.

Impending Changes in Our Use of Fuels

Recent Developments in the Processing of Coal to Increase Its Form Value, and the Possibilities of Extension of the Gas Industry

By ARTHUR D. LITTLE,[1] CAMBRIDGE, MASSACHUSETTS

AT THE recent notable International Conference on Bituminous Coal, President Baker, of Carnegie Institute of Technology, said, "In less than a generation the present methods of shipping coal to be burned in its raw state under boilers hundreds of miles from the mines will appear to have been primitive and rudely unscientific."

That there is sound basis for President Baker's prophecy is evidenced by the fact that the problem of converting coal to products of higher form value is already the subject of extensive and costly experimentation in many countries, including, of course, our own. The general problem has many aspects and is being attacked from many angles.

Foremost among these activities are the numerous processes for the so-called low-temperature carbonization of coal. Some two hundred of such processes have been listed, but it is doubtful if ten per cent of that number have been operated on anything approaching the commercial scale. Their distinguishing characteristic is that the coal is carbonized at temperatures rarely exceeding and often below 1100 deg. fahr. As a result, there are obtained a moderate volume of gas of high heating power and valuable, in place of gas oil, for the enrichment of blue water gas, an excellent smokeless fuel in the form of semi-coke, and from twenty to forty gallons of a thin tar, per ton of coal. This tar is markedly different from ordinary coal tar and has, instead, much of the character of petroleum. It may be cracked to yield 22 per cent of motor fuel of high anti-knock quality.

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In addition to these and other processes under development in this country, much serious work is being done on low-temperature carbonization in England and Germany, and it is claimed that one or two processes at least—the Coalite process in England and notably the K.S.G. process in Germany—are on a commercial basis. The latter is operating at Essen on a considerable scale, and a plant to handle 500 tons of raw coal a day is now under construction in South Wales.

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The problem of low-temperature carbonization in England is therefore the difficult one of operating at such low cost and of deriving such values from by-products that the semi-coke can be sold at substantially the price of the coal from which it is made, despite a shrinkage of 25 per cent or more in weight in passing from coal to smokeless fuel. In our own country the situation is much more favorable, for the product of processing bituminous coal is intended to enter into competition with high-priced anthracite.

There is a wide-spread and growing interest in the low-temperature

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carbonization of coal and increasing activity in the development of methods. These are progressively improving as the reasons for earlier failures are recognized. It is doubtful, however, if there is yet in this country a process that can be said to have established definitely a successful commercial status. It seems, nevertheless, altogether probable that within a short time certain of the processes now in the developmental stage will take an assured and important place in fuel technology.

Raw coal must continue to be for a long time to come the most economical fuel for large power stations except in situations that permit the tying together of low-temperature plants, gas works, and steam central stations, with delivery of semi-coke as boiler fuel and high B.t.u. gas for gas enrichment.

The broad opportunity for low-temperature carbonization is through the conversion of the immense available amount of cheap slack and screenings to high-grade domestic fuel.

The fuel problem in New England has been for years acute, despite the fact that there are great stores of coal in Massachusetts and Rhode Island. It is true that some people think it functions better as material for crucibles than on the grate, and the wise and lamented Professor Shaler did not advertise it favorably when he remarked that the safest place to be in at the conclusion of the Day of Judgment was a Rhode Island coal mine. Nevertheless, even the diamond will burn if you go about it properly, and so will these New England coals. They are very high in ash, but that ash can be reduced to seven or eight per cent. They are very low in volatile, but the volatile content can be raised. Both operations are in fact now going on.

We have all, from time to time, in recent years, heard much of the Trent process. In that process high-ash coal is subjected to wet grinding and thereafter agitated in a large volume of water, to which a moderate proportion of fuel oil has been added. The oil selectively wets the coal and gathers its particles into little balls not unlike caviar in appearance. The ash, for the most part, remains with the water and is washed away. The product resulting from the de-ashing process is a putty-like amalgam containing about eight per cent water, sixteen per cent oil, the remainder being low-ash coal.

For various reasons this amalgam has failed to find general acceptance as fuel for either domestic or power purposes. Quite recently, however, the process has been further extended, and the results obtained are of the most serious interest to New England and to the operators of anthracite mines.

In the process as now applied to Rhode Island coal and anthracite culm the amalgam is extruded and cut to briquet size. The briquets are then baked under regulated temperature conditions, which permit the recovery of the major portion of the oil. The finished briquets are equal, if not superior, to anthracite as a domestic fuel. They are of uniform size, dense, very hard, low in ash, and with about 8 per cent volatile. They ignite readily, burn freely without smoke, and hold the fire for a long period with maintenance of their shape.

The speed with which fuel developments are proceeding at this time and the dangers of prophecy are strikingly evident when these results are viewed in the light of the statement made only last November at the International Conference on Bituminous Coal, by so distinguished an authority as Marius R. Campbell. In his paper on "Our Coal Supply" Mr. Campbell said regarding the superanthracite fields of southern Massachusetts and Rhode Island: "In this field, coal has been mined from time to time at Portsmouth and Providence, in Rhode Island, and at Mansfield, in Massachusetts, but none of the operations were long-lived and it is doubtful if the material can ever be utilized as a fuel."

Of less immediate practical importance in this country, though of greater interest in its far-reaching implications, is the process of Bergius for the conversion of coal to liquid fuels. In the plant at Mannheim pulverized coal, made into a paste with oil, is heated to about 450 deg. cent. in an atmosphere of hydrogen under a pressure of 1800 or more lb. per sq. in. The coal is thereby largely converted into oil and tar, from which motor fuel, Diesel oils, lubricants, and heavy fuel oil are recovered. The crude yields and the character of the products are largely influenced by the nature of the coal used and vary from 93 to 140 gal. per ton of dry, ash-free coal.

As a measure of security in a country likely to have its supply of oil cut off in time of war the process is one of significant value. In the United States, with crude oil selling for as low as $1.00 a barrel, it has the allurement of a long-term endowment policy. The possibility of its application to the treatment of heavy petroleum residues for the production of motor spirit and light oils suggests, however, an earlier development here.

J. E. Bullard has recently pointed out that "the real competition in which the gas industry is involved is that between research and tradition. The gas industry has followed tradition rather closely. Its competing industries have turned toward research and are willing to scrap all tradition." He continues, "Unless real research work is done and on a scale commensurate to that being done by competing industries then the gas industry can take it for granted that it will have to relinquish more and more of its profitable business."

It is a timely warning, for the gas industry is entering upon a period of great expansion, in which the highest technical and scientific knowledge will be essential for the proper solution of the problems and the improvement of the opportunities which are before it.

The most significant of the developments immediately facing the industry are perhaps house heating and a greatly extended industrial use of gas. In case of both, gas offers the simplest and most reliable of the present systems of automatic heating. It can be burned at high efficiencies. The distribution of gas in underground mains is unaffected by weather or traffic conditions, and the service is among the most dependable of the utilities. Use of gas involves the consumer in no carrying charges. He pays for his fuel after it has been used. Under present conditions the householder pays more, but he receives more in comfort and convenience. In many industrial operations, however, the greater economy of gas is readily demonstrable.

The use of a gas flame to cool the refrigerator sounds paradoxical, but it may be recalled that wherever a motor-compressor unit is producing refrigeration a coal pile is somewhere being consumed to develop the electrical energy which drives the motor. Refrigeration by the direct use of gas thus eliminates a long chain of intermediate equipment. The required energy is furnished in much cheaper form; the apparatus involves neither motor, moving parts, nor lubrication, and, further, it makes small demand for service. Despite its present subordinate position in the art, the future of household refrigeration would seem to belong to the gas-fired unit.

Since gas has the highest form value of any type of fuel, a problem of outstanding importance to the gas industry is that of developing a thoroughly commercial method for the complete gasification of coal on the grand scale. The problem is apparently nearer to solution in England than with us. There some 200 Tully plants are operating, but they are mostly of small capacity, making less than 500,000 cu. ft. per day. In this process the coal is first carbonized in a vertical retort set over a water-gas generator, into which the coke descends. The retort is heated externally by the blow gas and internally heated by the water gas generated during the "up runs." The yield of mixed or double gas per ton of coal varies from 40,000 to 53,000 cu. ft. of 350 B.t.u.

Among those methods of complete gasification which have come into less general use mention should be made of the Kreisa system operating in Germany and Austria. It somewhat resembles the Tully process, but yields a gas of 450 B.t.u., provides for the continuous removal of ash, and, in place of a boiler for generating steam utilizes a metal checkerwork, which, heated by the gases of the blow period, and thereafter sprayed with water, provides, in balanced proportion, the steam required for the run.

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Impending Changes in Our Use of Fuels

Recent Developments in the Processing of Coal to Increase Its Form Value, and the Possibilities of Extension of the Gas Industry

By ARTHUR D. LITTLE,[1] CAMBRIDGE, MASSACHUSETTS

AT THE recent notable International Conference on Bituminous Coal, President Baker, of Carnegie Institute of Technology, said, "In less than a generation the present methods of shipping coal to be burned in its raw state under boilers hundreds of miles from the mines will appear to have been primitive and rudely unscientific."

That there is sound basis for President Baker's prophecy is evidenced by the fact that the problem of converting coal to products of higher form value is already the subject of extensive and costly experimentation in many countries, including, of course, our own. The general problem has many aspects and is being attacked from many angles.

Foremost among these activities are the numerous processes for the so-called low-temperature carbonization of coal. Some two hundred of such processes have been listed, but it is doubtful if ten per cent of that number have been operated on anything approaching the commercial scale. Their distinguishing characteristic is that the coal is carbonized at temperatures rarely exceeding and often below 1100 deg. fahr. As a result, there are obtained a moderate volume of gas of high heating power and valuable, in place of gas oil, for the enrichment of blue water gas, an excellent smokeless fuel in the form of semi-coke, and from twenty to forty gallons of a thin tar, per ton of coal. This tar is markedly different from ordinary coal tar and has, instead, much of the character of petroleum. It may be cracked to yield 22 per cent of motor fuel of high anti-knock quality.

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organizations, without vision, and far from realizing, either in their present practice, or in their preparation for the future, the possibilities of the industry. In many cases their communities could be more effectively and cheaply served through high-pressure transmission lines from large central gas plants. Natural gas is now piped 300 miles, and a projected line from the Texas Panhandle to Kansas City will be 450 miles in length. It is designed to deliver 36.5 billion cubic feet a year at a maximum pressure of 450 pounds.

In the Chicago district, along the Atlantic seaboard, and at a few points elsewhere, there exist great markets for manufactured gas within much shorter distances from the mines. There are few locations where adequate condensing water for super-power plants is available at the mine, but super-gas works are not subject to this limitation. We shall do well to watch the development of projects now under serious consideration in Germany for concentrating in the Ruhr the entire gas industry of the country and effecting distribution through high-pressure lines. We may find much food for thought in the following statement of the ambitious program of the Coal Utilization Company of Essen:

"Contrary to press statements that the new company is not concerned with the chemistry of coal, I must say here that its field is unlimited. It will use mechanical, electrical, and chemical methods to arrive at its object. All processes which use water, air, and coal as raw materials belong to the activities of this company. Coal which is otherwise unsalable must be changed to other forms of energy or to other materials for which there is a market. It is natural that the new company cannot begin at once all the methods of work. Its activities will be divided into those which can be immediately applied and those which must be left for the future. In the first class belong the distant supply of gas, district heating, the application of coal distillation, gasification and firing of powdered coal. For the future there are those modern chemical processes which have coal for their raw material but which require further scientific study and which, before technical application is possible, must be submitted to extensive investigation."

The modern chemical processes referred to are presumably those which Bergius, Fischer, and Patart described in more or less detail at the Pittsburgh Coal Conference. Mention has already been made of the first of these. That of Fischer produces gaseous, liquid, and solid hydrocarbons from water gas, while Patart disclosed a method of making acids, alcohols, and numerous other series of important organic compounds from the same product of the gas works.

Coke-oven gas is already being distributed over a radius of 62.5 miles from the Ruhr. It is believed that the problem of leakage over much longer lines under higher pressures "is entirely solved by processes for welding the gas lines."

In the Rhine-Westphalia coal district it is proposed to build a gas-collecting system which will extend from Hamborn to Hamm, into which the several coke-oven plants will pump their gas. This pipe line will follow the water courses through the coal district. The purification of the gas will be made at the end of the collecting system, where there will be located the gas holders and compressing station. Four sections of the main pipe lines have been projected from the Ruhr district:

1 Through Bremen and Hamburg to Lubeck and Kiel
2 Through Hannover and Magdeburg to Berlin and Stettin
3 Through Kassel and Thuringen to Saxony and later through Lower and Upper Silesia and the Saxon mining district
4 A line following the Rhine to Hesse, Baden, Würtemburg, and Bavaria.

It is claimed that the transmission of gas in great volume by pipe line is much less than the transport of coal by rail to local gas works, and in view of other savings it is planned to have one basic price for gas for the whole country. The distant gas transmission will, it is believed, be subject to the same economic laws as high-tension electric transmission. It would be intermingled with and unite the communal and private concerns, local distribution, and long-distance transmission.

In connection with this general plan much importance is attached to the possibility of utilizing cheap oxygen in water-gas sets, which would thereby operate continuously with a mixture of oxygen and steam. Our own studies indicate that such a generator might easily use 25 per cent less fuel for a given output and have twice the capacity from a given size. Such operation would permit the use of a solid hearth with slag removed in liquid form, thereby saving grate troubles and clinkering and making available low grades of coal with a low-fusing ash.

After generations of reckless waste in the utilization of the fuel resources of our country we are beginning vaguely to recognize the urge of that hoarding instinct which, it has been said, marks the dawning of economic consciousness in the progress of civilization. We have only to contemplate the situation into which opportunist development has brought us, as regards our coal, our oil, our natural gas, and our forests, to realize that most of the wastes delays, and difficulties which characterize that situation are due simply to lack of planning years in advance, and to our failure to embody in some coördinated general plan those lines of action which are well recognized by experts as essential to our proper development as an industrial nation.

No agency is better qualified to assist effectively in the development of such a plan or in the organization of those lines of research which must accompany this development than the Engineering Foundation, through which may be focused the integrated experience of our great national engineering societies.

Radiation from Gases

A PAPER on this subject is to be presented in the near future before the American Institute of Chemical Engineers by Hoyt C. Hottel, of the Department of Fuel and Gas Engineering of the Massachusetts Institute of Technology. In the past it has been customary to neglect radiation from gases in problems of heat transmission, due to the complexity of the computations involved. Hottel, however, has derived a number of charts which make it possible to calculate this radiation without difficulty. He has shown by a number of practical examples that this factor is far from negligible, and in fact in many cases is even greater than the transfer of heat by convection. His charts will be of great assistance in the design of any equipment involving heat transfer from gases. It has been known, for example, that the heat-transfer coefficients actually found in the convection tubes of cracking coils were larger than those calculated from the usual convection formulas, and it was therefore impossible to compute with any degree of accuracy the number of tubes required. By combining Hottel's charts and the convection formulas, values are obtained for the coefficients which agree closely with those actually found in practice.

This latest contribution from the Department of Fuel and Gas Engineering is a good illustration of one phase of the work carried on by them. In addition to formal instruction, both in the class room and in field work, the Department undertakes original investigations, and also endeavors wherever possible to apply to industry the results of research by other investigators, when these investigators have neglected to do so. Hottel's work falls under this last heading.

The original investigations of the Department are made both in the laboratory and on full-scale apparatus in the field. Research is now being carried out in the laboratory on rates of flame propagation in gaseous mixtures, hydrogenation of coal, synthesis of hydrocarbons, reactions in gas producers and water-gas generators, and on a number of other subjects.

In the various field stations located at plants of the Bethlehem Steel Company, Iroquois Gas Corporation, Cambridge Gas Light Company, and the Tide Water Oil Company, studies of a number of plant operations are being made. These include such subjects as heat transfer in regenerators, steam decomposition in water-gas generators, and efficiency and operating characteristics of crude-petroleum stills.

Recent Developments in the Application of Anti-Friction Bearings to Machine Tools

Illustrations of a Variety of Designs—Importance of Proper Lubrication and Methods of Preventing the Accumulation of Dust in Bearings

By R. F. RUNGE,[1] NEW YORK, N. Y.

THE SUBJECT of this discussion is rather far-reaching, if consideration is to be given to the numerous details entering into the proper application of anti-friction bearings. Due to limited time, it will be quite impossible to deal directly with specific details, and the discussion will therefore be confined to general principles.

It does not seem necessary to repeat here the fundamental practice in connection with anti-friction-bearing application, as that has been covered very completely in previous discussions and in the vast fund of information which has been widely distributed by the several leading ball-bearing manufacturers. This discussion will therefore deal with the newer developments with which there has now been sufficient experience to permit recommending them as proper machine-tool practice.

These principles may best be understood by referring to several illustrations which treat of the more important machine-tool elements. Certainly, anti-friction bearings have very definitely proved their superiority over other types of bearings in the more usual applications, such as change-speed gear boxes, loose pulleys, back shafts, feed screws, drilling-machine spindles, etc.

To those in the machine-tool industry who were pioneers in the application of anti-friction bearings many years ago, considerable credit is due for breaking down many of the old prejudices. This has resulted in a very decided advance and change of opinion during the last two years throughout the industry, so that we find today many important applications of anti-friction bearings in locations which only a short time back were considered questionable. The result obtained required considerable improvement in material, character of finish, and closer tolerances, accompanied by considerable metallurgical and physical research and also experience gained through actual use in the field, so that a surprising advance has been made over a short period.

It is desirable first to understand the improvement which those interested in this development are attempting to attain. Anti-friction bearings, to be successful, must show many times the life of the older forms of bearings or considerably less maintenance, resulting in greater number of productive machine-hours. The application must be one which is more foolproof than the older types of bearings, where a scraping-to-fit is necessary or adjustments are required. This is becoming more and more important as a greater amount of unskilled labor is finding its place in industry.

The next item of importance is the use of a bearing which has the absolute minimum of friction. This is quite obvious, as friction means wear, and wear definitely defeats accuracy and quantity of production. In this connection, it is unquestionably a fact that the more modern types of ball bearing, made to extreme accuracy and of the highest quality of material, will certainly provide the least friction, and for the same reason require the minimum or no adjustment.

Heat also is directly coupled with the subject of bearing friction. Heating on precision machines is of decided importance, as it will be immediately understood by those who are closely engaged with machine operations on precision work that such machines do not produce close tolerances consistently until the machine has attained its operating temperature. This materially affects machines in which automatic gaging of certain forms is used, so that machine heating due to friction in bearings plays an important part in percentage of scrap production.

If the above elements are realized through the application of anti-friction bearings, then it must necessarily follow that there will be a power saving of some magnitude, or, on the other hand, a greater amount of power delivered to the cutting tools, resulting in increased production.

It can therefore be considered, in general, that the advantages of anti-friction bearings have been classed here in the order of their importance and may be summed up as providing for greater production at less cost.

Rigidity is highly desirable in most machine-tool applications, thus reducing to a minimum the possibility of vibration. In that connection it might be well to mention here that an attempt has been made in the more recently designed machines, to provide heavier machines for a given operation, and in many cases where vibration has been present experience has shown that additional weight in the parts affected has very successfully overcome that objection. Mention is made of this condition for the reason that ordinarily the bearings are criticized for unsatisfactory results, whereas in many cases the trouble may be elsewhere.

In order to obtain proper results, it is necessary to analyze very carefully the conditions to be met with regard to the bearings as with any of the other machine elements. It is therefore most earnestly recommended that any one contemplating the use of anti-friction bearings should have the entire problem very carefully studied by the bearing manufacturer. The several high-grade bearing producers have had considerable experience, and full advantage should be taken of that experience.

The machine-tool manufacturers have been most cautious in the past in considering the application of anti-friction bearings to such parts as milling-machine spindles, lathe spindles, grinding-wheel spindles, and work-head spindles on the various types of machines. This is to be expected due to the requirements of consistent accuracy of performance and also due to the failures of past years, when the bearings had not been developed to as high a standard as at present, and improper types as well as improper mountings were used. This discussion will therefore be confined to the more important machine-tool-bearing locations, and an attempt made to indicate the more modern methods of application which are proving to be most satisfactory.

Some Applications

Fig. 1 shows the application[2] of ball bearings to a geared-head lathe. The important consideration here is the spindle mounting. On the chuck end of the spindle there are two pairs or four bearings recommended. The use of four bearings provides for maximum rigidity of the spindle and sufficient bearing capacity with the minimum outside diameter and maximum spindle diameter for sufficient torsional strength. Two bearings are used at the back end of the spindle, where the load is lighter. This mounting gives the maximum of rigidity and, the accuracy of all parts being held to very close tolerance, is sufficient for load distribution over the several bearings. In order to permit greater accuracy in the finishing of the parts, attention is directed to the mounting of the outer rings of the bearings in a bushing. The bushing permits the use of better material for supporting the outer rings of the bearings, and may be hardened where this is an exceptional requirement. In this type of application, it is always recommended that the bushing be ground in order to provide closer tolerance for fitting and a higher character of finish. The use of bushings will further permit through-boring for both the front and back holes in the headstock in one setting,

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For presentation at the First National Meeting of the A.S.M.E. Machine Shop Practice Division and the New Haven Machine Tool Exhibition, Mason Laboratory, Yale University, New Haven, Conn., September 6–9, 1927.

[2] The patent rights of this and other designs illustrated in this paper are protected.

and adds further to the ease of assembling by the use of capped bearings.

Where it is found in the assembly that the spindle does not line up with the ways of the lathe, the use of the bushing permits the scraping out or reboring of the bushing seat for proper alignment, and the outside diameter of the bushing can then be ground to suit the changed hole diameter.

It is obvious that it is necessary to eliminate all radial and axial play in the bearings, as well as in the fitted parts composing the bearing mounting. It is also necessary to confine the amount of movement permitted by elastic deformation between the balls and the raceways when the load is applied. This is provided for in the individual bearings, so that when the locknut *A* is set up, the bearings are loaded both axially and radially by establishing the proper amount of elastic deformation within safe limits to a point beyond the amount of elastic deformation set up by the working load. The axial and radial movements in the bearing under the working load are therefore held to extremely close limits, which is only a small percentage of the amount that must be provided for in an oil-film-supported bearing, with which it is always possible to change the position of the spindle by squeezing out part or all of the oil film. In the case of the ball-bearing mounting, the variations imposed by an oil film can be absolutely ignored. It is only necessary to grind spacing rings *B* and *C* to a slight difference in width, due to the accumulated variation between the widths of the outer rings and the widths of the inner rings. The individual bearings are interchangeable with each other, are reversible, and can be individually replaced. It might be added that spacing ring *B* is necessary to lock all of the inner rings between the nut and shoulder. Spacing ring *C* is used for the transference of thrust load from one set of bearings to the second set, so that there will be more than one row of balls carrying the thrust or axial load.

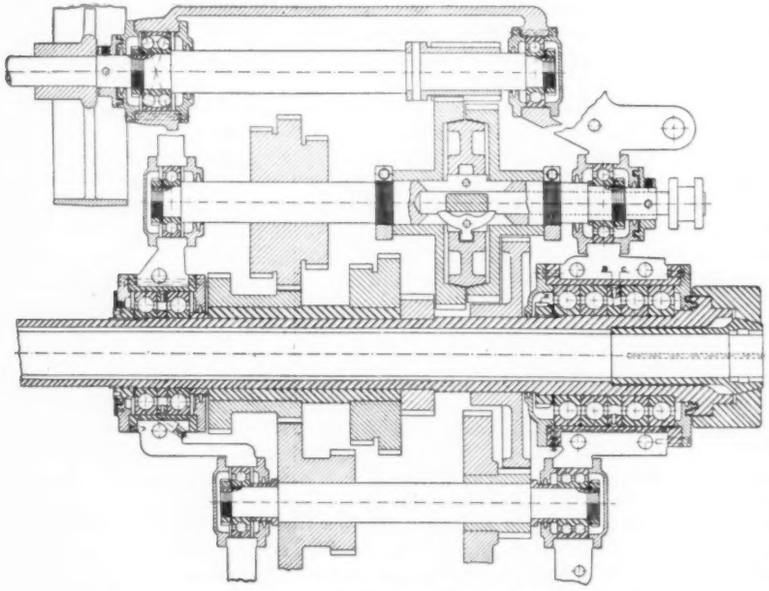

FIG. 1 APPLICATION OF BALL BEARINGS TO A GEARED-HEAD LATHE

The four bearings comprise a unit definitely clamped on the spindle and in the housing, thereby positively stabilizing the spindle.

The bearings in the auxiliary shafts in this lathe head are more or less general as to type of application. A possible exception to that may be pointed out through the use of the self-aligning type of ball bearing next to the pulley. This design permits the bearing to accommodate itself to any possible deflections due to the overhung belt load.

The spindle mounting is one which is also recommended for precision machines of the centerless, cylindrical, and horizontal surface-grinding types.

Lubrication is an important feature which will be covered later.

Fig. 2 shows a design which applies to horizontal milling machines, the important element of which is also the spindle. In this case, the main spindle is supported on two bearings at the front end and a self-aligning bearing at the back end. The arbor support also carries two bearings. In both of these instances where two bearings are used, the same principles of bearing construction are embodied in order to provide for initial elastic deformation between the balls and raceways. Attention is called to the construction of the arbor support, wherein the mounting can be removed without exposing the bearings or interfering with the lubrication. Although this design does not include bushings for holding the outer rings of the bearing, this is desirable for the front end of the spindle when space will permit.

On the intermediate gear there is shown a double-row, deep-groove ball bearing which comes directly under the tooth load, and a single-row bearing at the back end, principally for more rigid stabilization. The idler pulley is the usual type of mounting with regular single-row bearings. It may be pointed out here that four different types of bearings are used, which are composed of extremely accurate spindle ball bearings, self-aligning ball bearings, double-row, deep-groove ball bearngs, and single-row ball bearings, each of the types having been selected very definitely to perform a particular function.

Figs. 3*a* and 3*b* show two types of live tailstock centers for lathes and similar uses. Fig. 3*b* incorporates the usual type of flat-plate thrust bearing to withstand heavier thrust loads than can satisfactorily be carried on any of the radial types of bearings. This thrust bearing is required to carry the load in one direction only, as indicated by the arrow. When the tailstock is without load it is important that the stationary ring of the thrust bearing be prevented from dropping, and for this purpose a series of light springs (marked *A*) are provided in the backing plate to keep a slight reverse pressure on the bearing.

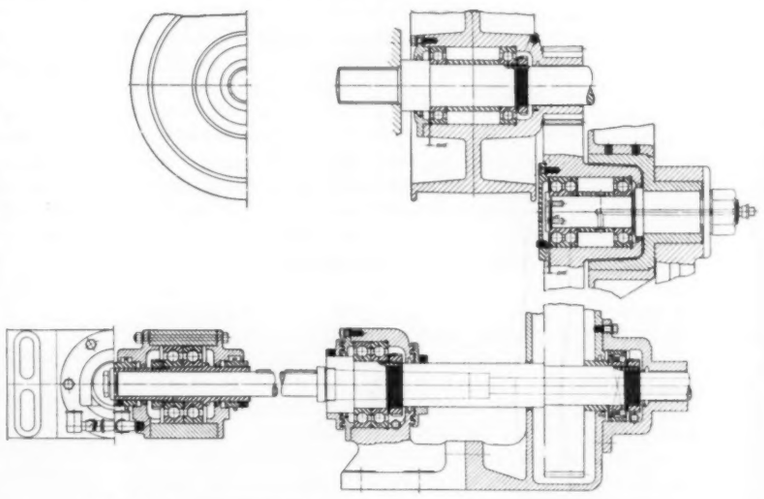

FIG. 2 APPLICATION OF BALL BEARINGS TO A MILLING MACHINE

It will be noted that the spherical type of roller bearing is introduced in this construction. This is for the purpose of obtaining greater bearing capacity within a limited space. It might be noted that this type of bearing has slightly more than twice the capacity of the equivalent-size single-row ball bearing.

Fig. 3*a* shows a live tailstock center employing one double-row ball bearing to take the combined thrust and radial loads and on the front end a single-row bearing for radial load only. The advantages of these designs are that there is less heating set up than with dead centers, that there is a slight reduction in power required, and that there is an almost entire elimination of redressing of the center points, permitting more accurate positioning of the work, as the centers can be brought up metal-to-metal.

Inasmuch as there are many lathes, milling machines, etc.,

equipped with simplified countershafting, the design of Fig. 4 is recommended as one which provides for maximum efficiency, minimum space requirements, minimum weight, and minimum attention. While there is nothing particularly new about this application, attention is called to it as in many cases a very inefficient type of countershaft is supplied with the machines, and if maintenance and power saving are to be considered in the machine tool itself, they are equally important in the countershaft.

The designs so far presented have dealt mainly with moderate speeds and comparatively high load. In the grinding machine the conditions are generally reversed, speed being the most important consideration and load conditions secondary.

The mounting shown in Fig. 5 is for a grinding spindle for external work. In this it will be noted that the bushing principle is again used. This provides for greater accuracy of bearing mounting, which is of still greater importance where higher speeds are encountered. The same special type of spindle bearing is recommended in this design. Here, again, where load capacity is not so important, the use of two bearings at each end of the spindle is recommended.

Fig. 6 shows a small high-speed internal-grinding spindle. Due to the great amount of trouble which has always been experienced with sliding bearings on high-speed work, ball bearings came in for earlier consideration on this application than elsewhere, and there has probably been more experience and greater progress made on the internal spindle than on any other type. Where a few years ago these spindles were operated at about 10,000 r.p.m., speeds of approximately 25,000 r.p.m. are now being regularly used, and in certain unusual cases from 50,000 to 60,000 r.p.m. are being attempted. In these higher speeds there are several important considerations aside from the bearings, but without proper bearing application, any other developments, such as high-speed drives, etc., are of little consequence.

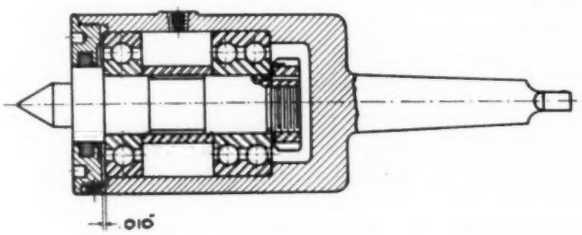

Fig. 3a

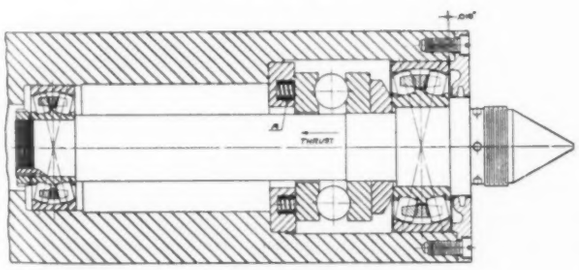

Fig. 3b

FIGS. 3a AND 3b APPLICATION OF BALL BEARINGS TO TWO TYPES OF LIVE TAILSTOCK CENTERS

Fig. 6 shows again the double-bearing mounting at both the front and rear ends of the spindle, utilizing specially made spindle bearings. The pair of bearings at the front end are locked endwise in order to stabilize the spindle, and it probably does not require mentioning that the stabilizing bearing should always be located nearest the grinding wheel so as to keep to a minimum the amount of change of wheel position due to expansion of the spindle because of heat. While this principle applies particularly to grinding spindles, it also is of importance on any other type of spindle. This design then permits the expansion or contraction of the rear end of the spindle, as the two bearings at this point are permitted to float axially. Due to the special spindle-bearing construction, the two bearings in this design may also be locked through the inner races by a nut, thereby taking out all of the radial and axial looseness and providing for the amount of initial elastic deformation.

The reason for providing for initial deformation in bearings for high-speed grinding-spindle mounts is somewhat different than for those on the heavier spindle applications. In the high-speed internal spindle it is not only necessary to eliminate any play from the bearings, but, due to the high speed of the balls in the raceways and very quick acceleration, it is important that the balls be not allowed to skid on the unloaded side of the bearings. When initial elastic deformation is provided for in the bearing, each ball is definitely driven through the inner race by positive contact. This skidding which takes place in the bearing will naturally set up a slight amount of wear, thus causing looseness.

Fig. 7 is a rather interesting application in view of the fact that

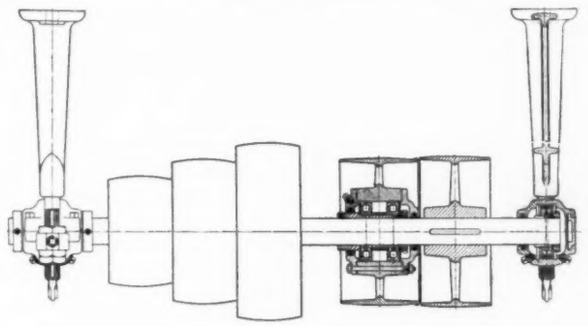

FIG. 4 COUNTERSHAFT EQUIPPED WITH BALL BEARINGS

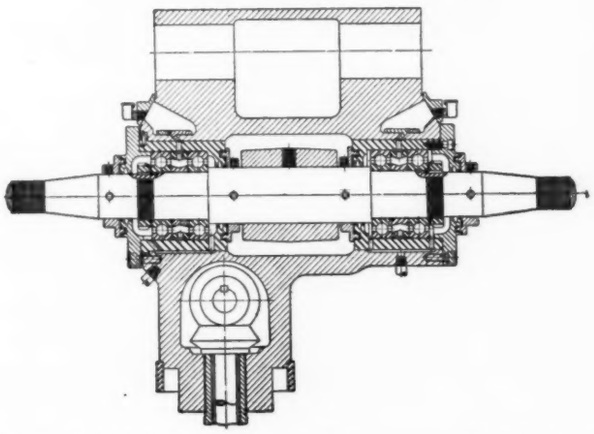

FIG. 5 GRINDING-MACHINE SPINDLE EQUIPPED WITH BALL BEARINGS

for many years it had been considered quite undesirable to attempt to carry the work-head spindle of grinding machines on ball bearings, the general objection being that, due to the slow speed of the work spindle, any eccentricity or irregularities of the bearings would be transferred to the work being ground. The method of mounting as shown in this design, in consideration of the accuracy of the special spindle bearings, completely overcomes that objection and is responsible for even more accurate work than has been generally done on spindles having sliding bearings, as here again the variation in oil film in the sliding bearings is completely eliminated. This construction follows closely those shown previously in so far as bearings and mountings are concerned.

LUBRICATION

Proper lubrication for ball bearings is important, although it is commonly known that they require a very small amount of lubrication. It is quite necessary, however, that that be of proper consistency, and care should be taken to use a lubricant free from acids and foreign matter.

There have been certain tendencies toward the use of grease in precision and high-speed applications. Grease may be used under certain conditions, but due to the great variety of viscosities of grease, and also the numerous fillers which are used, grease lubrication is subject to a wider range of variation than is oil and is therefore less controllable. For such applications as have here been

discussed, years of experience have very definitely shown that oil lubrication is preferable.

In the design shown in Fig. 7, as well as in most of the others, it will have been noted that oil lubrication is provided for in that oil is fed to the bearings through wick filters. It is a very common occurrence in supplying additional lubricant for machines in operation in the shops, that the end of the oil can may contain a certain amount of grit or chips; and in the case where grease is used, many times the grease has picked up, through exposure, considerable gritty foreign matter. It is rather surprising to note the amount of fine grit which will settle into an open grease can from the atmosphere. A small amount of abrasive which finds its way into the bearings is likely to develop bearing looseness due to abrasion. This is usually misconstrued as bearing wear, which it is in a sense, but not inherently due to the bearing itself. The filtering of lubricant before it enters the bearing housing has very definitely been proved a decided advantage, and on that basis alone grease is eliminated as a proper lubricant as it is not subject to efficient filtration.

As has been mentioned in a previous paragraph, it is advisable on precision machines to reduce as much of the heating as possible. Where grease is used, there is grave danger of generating additional heat through churning. This is also true where the bearings are

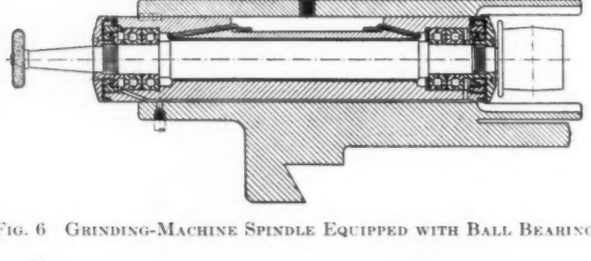

FIG. 6 GRINDING-MACHINE SPINDLE EQUIPPED WITH BALL BEARINGS

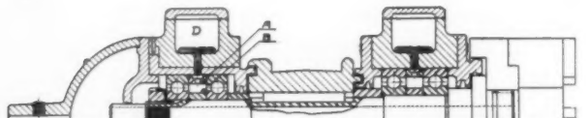

FIG. 7 APPLICATION OF BALL BEARINGS TO WORK-HEAD SPINDLE OF GRINDING MACHINE

partly submerged in a reservoir of oil. This is eliminated in the designs presented, in that the oil is fed through the wick as a filter and from there through the spacer ring *A*. Part of the oil may find its way into the bearing through capillary action along the internal surface of the spacer ring *A*, but most of the oil will drop on to the spacer ring *B*, the result of which is that most of the oil entering the housing is atomized. A reservoir is not permitted to form, as the oil will feed through the bearings and out through drain holes *C*. This really develops into a drop feed from oil reservoir *D*, as the feed through the wick is easily controlled. This has an additional advantage in that, should any foreign matter or abrasive find its way into the bearing housing, there is a tendency for the oil to carry it out through the drain holes. In certain instances where capillary feed is advisable, the wick is permitted to rub on a rotating part, which not only acts as a wiper for additional oil suction, but also for atomizing.

Where automatic lubrication, or a centralized system, is used for all of the bearings on a given machine, this same principle of lubrication can be applied.

This principle of lubrication cannot be too strongly emphasized, as foreign matter and improper lubrication in any type of bearing are extremely injurious, as has well been demonstrated.

From the standpoint of foreign matter getting into the bearing housing, the design of enclosures is of equal importance. In the design in question, at the three positions *E* is shown what is termed a labyrinth seal. This may be of the single or multiple type. Those shown in Fig. 7 are single, whereas those shown in the design in Fig. 6 are multiple. This construction has proved quite satisfactory, although there still remains room for improvement. In the case of high speed, grooves filled with felt, cork, or other compositions have not proved entirely satisfactory. The rubbing friction is sufficient to burn the material, and in addition, any soft material acts as an absorbent of abrasive, and over a period of time sets up a lapping condition, accompanied by heat and wear.

In closing, the importance should again be emphasized of making a careful analysis of the conditions to be met in the various types of machines; that full advantage should be taken of the information the bearing manufacturers are in a position to supply, and that standardization should be definitely kept in mind. It is fair to say that the initial installation of ball bearings, if made standard practice on machine tools, should show very little, if any, higher cost than many of the present types of sliding bearings, to say nothing of the decidedly lower maintenance costs of ball bearings in comparison.

The machine-tool industry, in the author's twenty-two years of observation, is now making greater headway than at any previous period in the application of better bearings, and a safe prediction would be that the next important step in the way of improvement will be a more general adoption of ball bearings as standard equipment in the machine-tool industry.

An Analysis of the Motor-Bearing Problem

THE AUTHOR reviews the work of several committees of the Association of Iron and Steel Electrical Engineers dealing with bearings in motors and some papers on the same subject. The author's paper is of interest as, contrary to what appears to be the present trend, he presents arguments in favor of sleeve bearings as compared with anti-friction bearings. He claims that while sleeve bearings collectively both in mill manufacture and maintenance do not make a fair comparison with the factory-made precision anti-friction bearing, from an operating standpoint their simple construction and ease of fabrication by an average mechanic are a form of insurance against long delays when a bearing fails and a spare is not at hand.

Furthermore, when the comparison is made not with a home-produced sleeve bearing but with one turned out and furnished by the manufacturers, a different light is thrown on the subject. Long ago their research engineers found out that the proper mixing of materials, and use of different mixes for different classes of work were essential to good sleeve bearings, also that this mix has to be properly handled during melting; that the shell has to be properly prepared; and many other precautions have to be taken so that their bearings are made right. Then too, they realized that mill oilers never look at oil gages, so they designed overflow pipes that would allow excess oil to run out of the bearings faster than the oiler could pour it in. They thus eliminated this defect. They also found that they could design a housing that would prevent the lubricant from getting outside the bearings, and prevent the outside dirt from getting inside. When all this was realized, modern sleeve bearings were ready for the market, and can be purchased with a guarantee of running at least a year without additional lubrication.

The real advantage, in the opinion of the author, of the ball or roller types of bearings over the sleeve bearings is in the starting friction which, in the case of the former, is practically the same as the running friction and is comparatively high in the sleeve bearing.

In the sleeve bearing, the oil passing back to the oil well carries heat away from the point of generation, while balls cannot escape from the bearing for cooling, which must take place by conduction through the steel of the races of the housing and shaft. It is also known that brass sleeve bearings will stand high temperatures, but the babbitt bearings must be kept much cooler than the maximum allowable temperatures on anti-friction bearings, due to the low melting point of babbitt. (Frank W. Cramer, in the *Iron and Steel Engineer*, vol. 4, no. 7, July, 1927, original paper, pp. 329–331 and discussion p. 332, *pc.*)

Anti-Friction Bearings in Ordnance Work

Rapid and Easy Manipulation of Heavy Ordnance Made Possible by the Use of Ball and Roller Bearings; Some Designs for Heavy-Load Conditions

By F. BRAUER,[1] WATERTOWN, MASS.

EARLY in the history of modern ordnance, the Ordnance Department of the Army recognized the necessity for the introduction of anti-friction bearings. In fact, in several of the mechanisms in gun carriages it would have been utterly impossible to obtain the results required in specifications for ordnance without anti-friction bearings.

When rolling replaces sliding at the bearing surfaces, there is a decrease in the coefficient of friction to a fraction of that of plain bearings. This reduces the power consumption and permits the introduction, if motor-driven, of smaller motors, while for hand-power operations it decreases to a considerable extent the effort exerted by the gun crew.

Lubricating difficulties with plain bearings, which require a comparatively large amount of oil to maintain the oil film, are greatly reduced by the introduction of anti-friction bearings, due to less exacting requirements. With anti-friction bearings, lubrication is not so important and the bearings, if the lubricant supply should fail temporarily, will still continue to operate.

While in most cases the rotating mechanisms on seacoast armament, including the anti-aircraft projects, are of slow speed in comparison with metal-working and wood-working machinery it is essential that quick response to efforts, whether by motors or by hand, be obtained, and as ball or roller bearings have practically the same friction at starting as when running, the introduction of anti-friction bearings becomes imperative.

Seacoast armament is not in continuous operation, and in most cases is "out of service" for a considerable length of time; and as its anti-friction bearings require comparatively little lubricant, are quite often packed with grease instead of oil, and are provided with effective housing seals, it is possible to place it in service in a comparatively short time, while with plain bearings careful lubrication would be necessary before starting to prevent seizing of journals and other bearings.

When standing for a considerable length of time, the oil film in plain bearings will disappear, and the bearings may freeze, which may necessitate dismantling at least partially for cleaning and oiling. Plain bearings require constant attention and inspection. Even with elaborate lubrication systems there is danger of seizing. In anti-friction bearings, however, the loads are carried on metal-to-metal contacts, and therefore are largely independent of conditions which seriously affect plain bearings. As long as the metal surfaces in ball, roller, or thrust bearings are not impaired, these bearings will still continue to operate and give dependable and steady performance.

With the right material, correctly heat-treated, and provided the stresses brought upon anti-friction bearings are sufficiently low, there should be no tendency to wear, if dirt is excluded from them and abrasion prevented. In many parts of the gun carriage it is essential that the nominal clearance between the revolving parts be small in comparison with the clearance usually allowed in plain bearings. The internal looseness can be reduced to the very minimum in ball- and roller-bearing designs; in fact, recently it has become necessary in some of the roller bearings on anti-aircraft mounts to omit internal looseness and have absolute metal-to-metal contact. Such a case is described more fully in this paper.

Specific Illustrations and Descriptions

One of the earliest applications of roller bearings to ordnance was in the traversing wheels of the 8-in. disappearing carriage, Model 1894, for limited fire. The traversing wheels were conical, working on a roller path, and as it was necessary to reduce the journal friction, cold-rolled-steel rollers, held in distance rings, were used.

One of the essential motions in the control of gun fire not only requires the rotation of the gun, but practically the whole mount with the exception of the lower part, or base ring, which is securely bolted to concrete foundation. To obtain this motion involving weights from a few thousand pounds for the smaller-caliber guns, to 1,000,000 lb. for the largest caliber guns, either thrust ball bearings or conical roller bearings are used. Not only must these bearings sustain the dead weight of the rotating parts, but also the force due to the overturning movement when firing at 0 deg. elevation, while much greater stress is placed on these bearings when firing at high elevations.

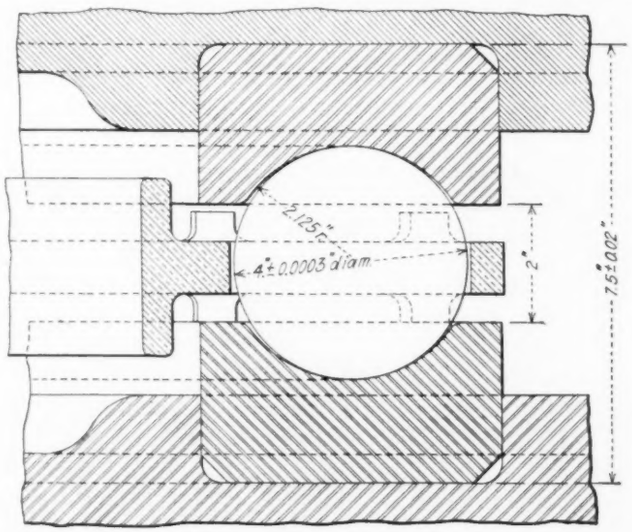

Fig. 1 Section of Lower Pintle Thrust Bearing, 14-In. Railway Mount. Diameter at Center of Balls, 51.125 In.

The heavy roller thrust bearings of the 16-in. barbette carriages, Models 1919 and 1919M1, carry a load during firing amounting to 2,380,000 lb., which is the weight of the rotating parts plus the component of the firing load at 65 deg. elevation. It is obvious, that without roller thrust bearings and under conditions illustrated above, where the mean diameter of the roller races is about 28 ft., there would be a great amount of sliding friction, and hand operation, which must be provided for in event of failure of electric power.

Pintle Bearing, 14-In. Railway Mount

In the 14-in. railway mount, Model of 1920, the traveling weight of which is 730,000 lb., the ball thrust bearing consists of an upper race, a lower race, and thirty-four balls 4 in. in diameter. Both races are the same, the diameter at the center of the groove being 51.125 in. A section through the bearing is shown in Fig. 1.

The races as well as the balls are made of chrome bearing steel, hardened and ground, and have a Shore scleroscope hardness number of 90 and better. The races are capable of carrying a sustained load of 100,000 lb. on one ball applied at any point in the circumference of the groove, and each ball will stand a load of 100,000 lb. when placed between the finished races without showing any permanent deformation or surface cracks.

The balls were tested by the manufacturer under a Riehlé testing machine using the three-ball method, wherein three balls are superimposed, the center ball being the one actually under test. The three-ball method has proved itself to be the most reliable

[1] Chief Draftsman, Watertown Arsenal.

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testing method, and is replacing the old way of testing one ball between two hardened-steel plates. The three-ball method is more severe, due to the fact that the ball under test is supported only by an actual point of contact instead of two flat surfaces, and the results are therefore more accurate, consistent, and reliable.

The crushing strength of steel balls under the three-ball method is determined by the manufacturer by the relation $1000 \times D^2$ where

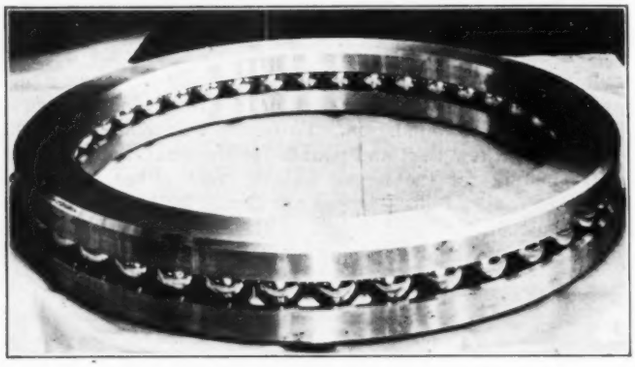

FIG. 2 LOWER PINTLE THRUST BEARING, 14-IN. RAILWAY MOUNT, AS ORIGINALLY MADE WITHOUT DISTANCE SPACER

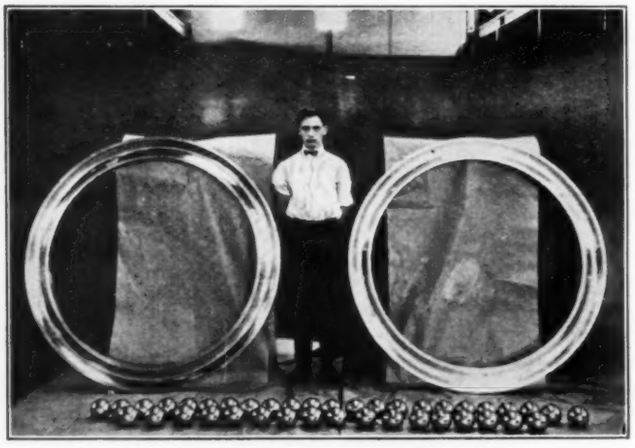

FIG. 3 UPPER AND LOWER RACES AND FORTY 4-IN. BALLS USED IN LOWER PINTLE THRUST BEARING, 14-IN. RAILWAY MOUNT

D represents the diameter of the ball in eighths of an inch. This means that a 4-in. ball would crush at a load of about 1,024,000 lb., and as the design requires only a strength of 100,000 lb., an ample factor of safety is obtained.

From the above analysis of this large ball thrust bearing, it would thus be possible to subject it to a perfectly safe load of 3,400,000 lb., providing the stresses were equally divided on all the balls, and it would deform under a load of 34,816,000 lb. uniformly distributed.

Under fire, the static load on this bearing plus the component of the firing load with gun at 50 deg. elevation is 1,246,000 lb., and as a great many rounds have been fired at all elevations, it has been demonstrated that the roller bearing is a complete success.

In Figs. 2 and 3 are shown the forty balls which were originally provided without distance ring or spacer. Subsequently it was found necessary to dispense with six of these balls and introduce the spacer indicated in Fig. 1.

BEARINGS FOR HAND-OPERATED MECHANISMS

In 1896 the Ordnance Department completed the design of a 12-in. disappearing carriage, Model of 1896, in which elevation, traversing, and retraction were accomplished by man power. Electrification of seacoast armament not having been introduced until 1901, it therefore became necessary to use anti-friction bearings in these mechanisms.

The roller bearings used were designed for manufacture at a Government arsenal. The roller cages or bushings were made of bronze in one piece, cored for the reception of the rollers which were made of cold-drawn steel, rough-filed, free from bunches, sprues, etc. Any inequalities or distortion of the cages had to be straightened so as to hold the rollers parallel to the axes of the shafts.

While these bearings were a great improvement over plain bearings, and worked satisfactorily under the loads brought upon them, the manufacture by the Government was soon thereafter discontinued, as bearings could be obtained commercially from one of the pioneers in the field of roller bearings, the designs meeting all requirements and giving better results.

The ball thrust bearings used in the mechanisms were likewise manufactured at a Government arsenal, but this practice was soon discontinued in favor of commercial bearings which could be obtained of better qualities and at a less cost. It is a fact, however, that bearings made at a Government arsenal in 1896, and subsequent bearings made a year or two after by a bearing concern, are still giving good service on carriages at the fortifications.

In these early designs precautions were taken to prevent entrance of dirt, by means of seals in the form of recesses in adjacent parts to the roller bearings or by collars having grooves filled with felt impregnated with oil. When carriages are "out of service," these bearings are completely packed with grease, and about once a year or whenever maneuvering or target practice require, are cleaned out. When again put "in ordinary," the bearings are again packed with grease and sealed up.

TRUNNION BEARINGS

The most severe stresses that roller bearings have been subjected to in ordnance design are in the trunnions of cradles in which the gun slides during the recoil. Anti-friction bearings in trunnions have been applied for heavy duty in gun carriages from 3 in. up to 16 in., in order that the elevation and depression may readily be accomplished in the shortest possible time.

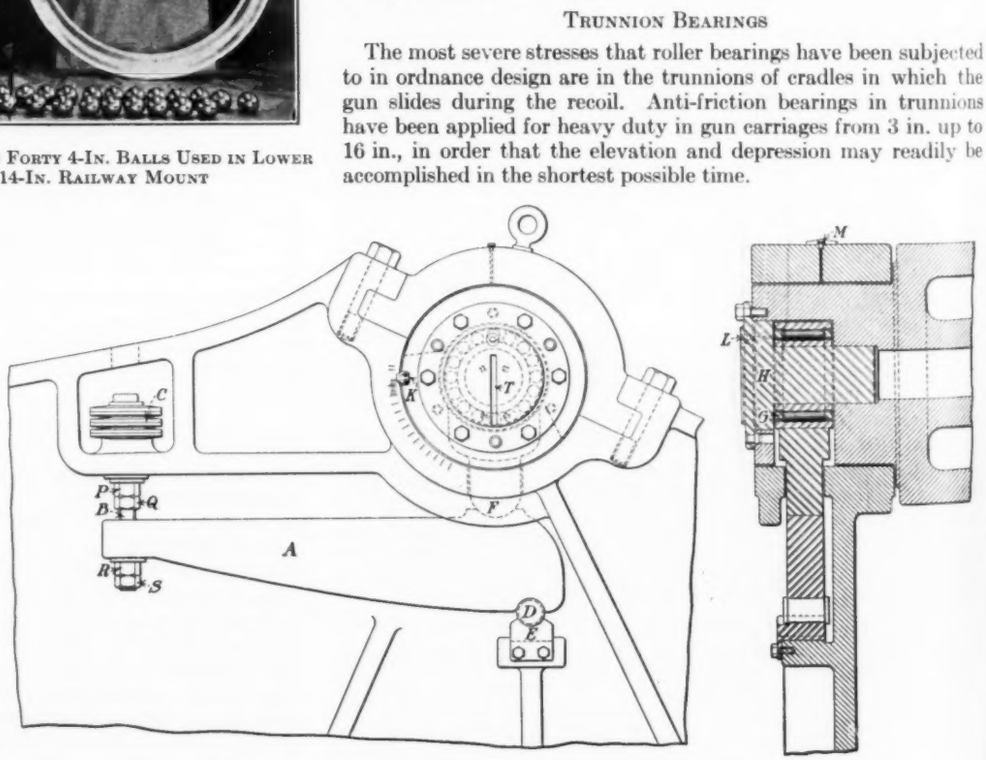

FIG. 4 ANTI-FRICTION DEVICE, 16-IN. BARBETTE CARRIAGE

A	Lever	*F*	Crutch	*M*	Oil Plug
B	Spring Rod	*G*	Roller Bearing	*P*	Spring Rod Collar Nut
C	Belleville Spring	*H*	Bearing Pin	*Q*	Spring Rod Lock Nut
D	Crutch Spool	*K*	Elevation Pointer	*R*	Spring Rod Collar Nut
E	Step	*L*	Nipple	*S*	Spring Rod Lock Nut
		T	Slot		

By the introduction of levers and fulcrums and Belleville springs, in conjunction with the anti-friction or roller bearings, it is possible to manipulate with perfect ease and in a short interval of time the tipping parts consisting of the gun, the cradle, the cylinders, and other details which rotate around the trunnions of the cradle. The dead weight of these parts amounts to 500,000 lb., or 250,000 lb. on each trunnion in the case of the 16-in. gun barbette carriage, Model of 1919. This arrangement is shown in Figs. 4 and 5. Levers *A*, one on each side of the carriage, are supported at one end by spring rods *B* which pass through and are supported by Belleville springs *C*. The other ends of the levers are supported on crutch spools *D*, which in turn are supported by steps *E* which are bolted to a web on the side frames. The crutches *F*, their upper faces being curved to fit the outer sleeves on the roller bearings, are placed on their seats on the levers. Trunnions on the cradle which are shown in cross-section in Fig. 4 are bored to receive bearing pins *H*, and the roller bearings *G*, and the lower part of the trunnions are cut out to provide space for the upper end of the crutches *F*. Bearing pins *H* with the roller bearings *G* are put in the trunnions, and the bearing pins are bolted in place. After the tipping parts have been placed in the side frames, the trunnions are raised from their seats in these frames and supported by crutches *F* in such a position that there is no contact between the trunnions and bearings in the side frames. This adjustment is made by means of nuts *P*, *Q*, *R*, *S*, and spring rods *B*. The weight of all the tipping parts is now carried on the roller bearings, and this condition exists at all times except when the gun is fired, at which time the force due to the powder gases at elevations above 0 deg. compresses the Belleville springs *C*, and the trunnions seat themselves in the main bearings in the side frames. After the effects of the force due to the powder gases have been dissipated, being absorbed by the recoil mechanism, the trunnions return to their original position. Lubrication of these bearings is provided by use of Alemite lubricators. Thickness gages, one for each trunnion, are provided with each carriage so as to gage the clearance between the trunnions and the trunnion beds. The thickness of these gages equals half the diametrical clearance, the exact thickness being determined during the shop inspection, on account of possible variation in the machining of the bored and turned parts. In order that the trunnions may float with perfect freedom in a horizontal plane, it is necessary that the exact opening for gaging this flotation be determined for either side of the carriage, the anticipated diametrical clearance being 0.04 of an inch, which will make the gages 0.020 in. These may vary by a few thousandths depending upon the exactness of the machining to basic dimensions.

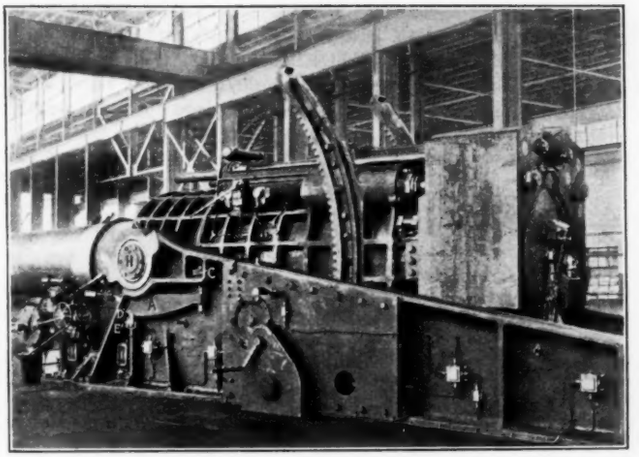

FIG. 5 LEFT SIDE, 16-IN. BARBETTE CARRIAGE, SHOWING ANTI-FRICTION DEVICE

A Lever *C* Belleville Spring *D* Crutch Spool *E* Step *H* Bearing Pin

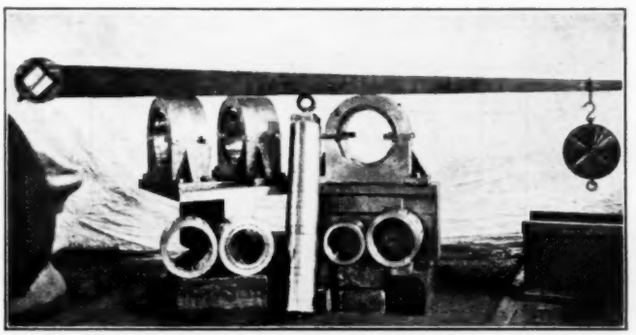

FIG. 6 FIXTURE FOR TESTING ANTI-FRICTION TRUNNION BEARINGS

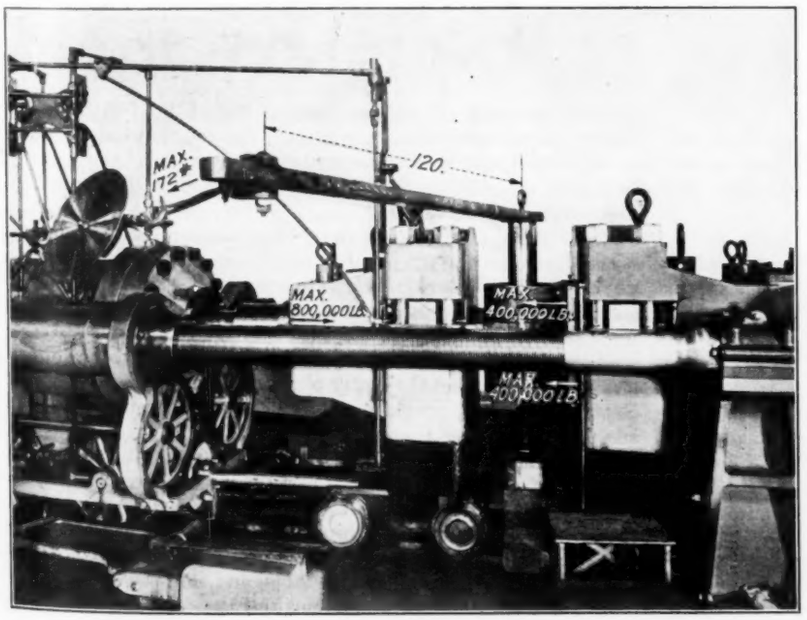

FIG. 7 FIXTURE FOR TESTING ANTI-FRICTION TRUNNION BEARINGS ASSEMBLED IN TESTING MACHINE

TEST OF TRUNNION BEARINGS

A test was made in 1919 to determine whether the bearings designed for the trunnions of this carriage would stand the strain that would be brought upon them, and the results obtained surpassed all expectations, in that it was possible to subject these bearings to a load of 800,000 lb. without deformation or change in dimensions.

In the test three pedestals shown in Fig. 6 were used. One of the bearings was placed in one of the heads of the testing machine, the two other bearings joined by a plate in the other head of the machine, and an axle inserted as shown in Fig. 7. At the end of the axle a 120-in. lever was attached, at the end of which a spring balance was applied, so that for various increments of loads, by rotating the shaft, the force could be readily ascertained. By using this apparatus a very accurate test of these bearings under various loads was made.

The roller bearings, that is, the inner and outer sleeves, as well as the rolls, were made of chrome bearing steel, the rollers having a Shore scleroscope hardness of 90 to 100, and the inner and outer sleeves a scleroscope hardness of between 85 and 95. The roller bearings are shown in Fig. 8. From Table 1, it will be noted that the loads were applied by increments of 50,000 lb. The starting-force readings were recorded by means of a dial spring balance fastened to the lever arm of 120 in. in length. This lever fitted over the top of an axle 7 in. in diameter which served as a spindle for the three sets of rollers held in the fixtures in the testing machine.

In Fig. 9, the coefficient of friction and the torque as functions of the load have been plotted from the data of Table 1. It will be noted that at the load of 50,000 lb. the coefficient of friction is 0.00105, and that for subsequent increments of load of 50,000 lb. up to 550,000 lb. the coefficient of friction is less. From that point on it gradually increases up to 80,000 lb. applied load.

As several tests made on different bearings of the same type gave practically the same results, these variations can be explained by the fact that at the application of a load of 50,000 lb. the bearing was moved considerably back and forth by effort on the end of the lever, thus probably ironing out any small irregularities that could not be detected by measurements, so that with subsequent loads the coefficient of friction was thereby reduced slightly. It was also noticed in several of these bearings that at the load of 250,000 lb. the coefficient of friction was slightly higher than at the 300,000 lb., and this can only be attributed to slight irregularities which have been ironed out, or a change of position of rollers. At any rate, it gives a fair illustration of conditions which may be met in bearings of this size, and under heavy loads.

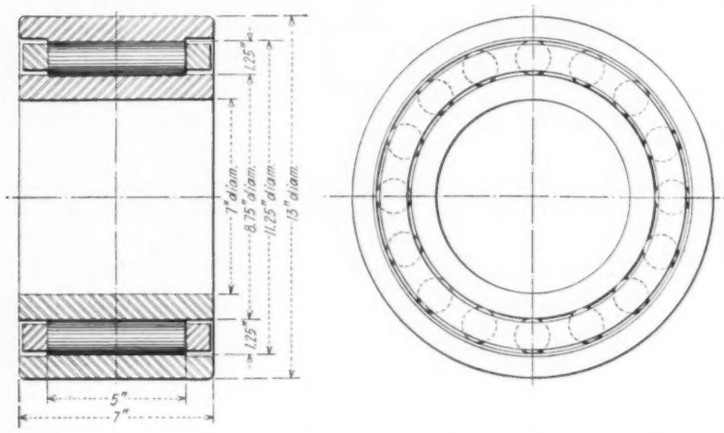

FIG. 8 ROLLER BEARING FOR TRUNNION OF 16-IN. BARBETTE CARRIAGE

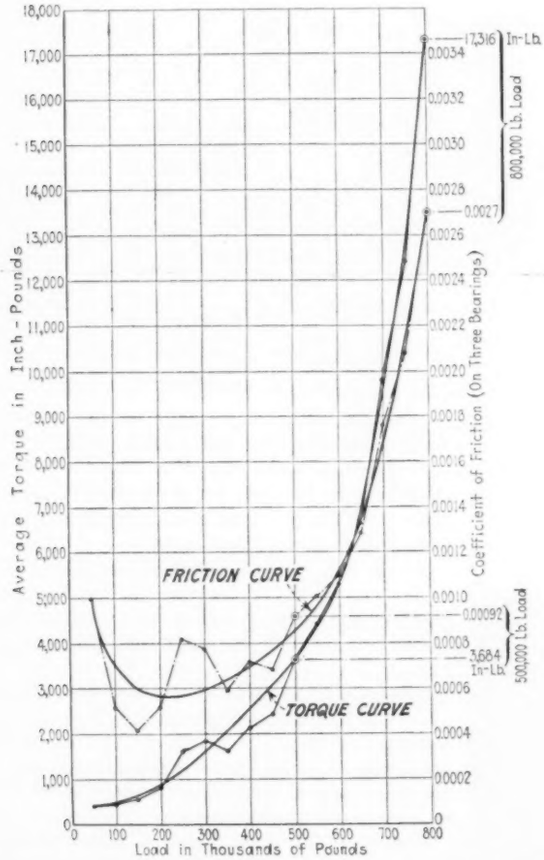

FIG. 9 TEST ON ROLLER BEARINGS FOR 16-IN. BARBETTE CARRIAGE

Although not shown in the illustration, a counterpoise was hung on the lever placed at 180 deg. from the lever arm so as to balance the "over-hang" of lever and spring balance. As each increment of 50,000-lb. load was applied, the starting force was recorded through an angle of 72 deg., this being the angle through which this bearing will work when inserted into the trunnions of the 16-in. barbette carriage, each movement representing from minus 7-deg. depression to plus 65-deg. elevation. Three readings of the starting force were taken at each angle of 12 deg., thus making a total of 18 readings for each increment of load applied.

For each increment of 50,000 lb. above 150,000-lb. load, the bearing was taken out, examined, and rollers and sleeves or casings carefully measured to detect any deformation which might have occurred. Special care was taken in measuring the rollers which came directly in line where the force was applied, and lying within the 72-deg. service angle.

The observations and measurements during and after the test demonstrated that the rollers and casings were safe for all loads applied in this test. Since the maximum of 800,000 lb. applied to the middle roller bearing, or 400,000 lb., which would be the reacting force on the two other roller bearings, produced no deformation, and as the actual static load on these roller bearings when the tipping parts of the 16-in. barbette carriage are applied thereto would be 500,000 lb., or 250,000 lb. at each trunnion, it was the opinion that these bearings could be used in service with security. Many rounds have been fired from guns mounted on the 16-in. carriages, and no failures of bearings have been recorded.

TABLE 1 DATA SHEET, NOTATION, AND FORMULAS, TEST OF TRUNNION ROLLER BEARING FOR 16-IN. BARBETTE CARRIAGE

W = Load applied in pounds
F_a = Average starting force in pounds
T_a = Average starting torque in inch-pounds
R_c = Distance of center of rollers to center of bearing in inches
r = Radius of rollers
u = Coefficient of friction
$T_a = 120\,F_a \quad T_a/R_c = Wu/r \quad u = rT_a/R_cW$

Load applied	Starting force at end of 120-inch lever. Through angle of 72 deg.						F_a	T_a	u
W	1	2	3	4	5	6			
50,000	3	4	4	3.5	4	3	3.5	420	0.00105
100,000	4.5	4	6	0.5	1	5	3.5	420	0.00052
150,000	3	5	5	0.5	4	3	4.25	510	0.000425
200,000	5.5	9	9.5	0.5	7.5	10	7.00	840	0.00052
250,000	25.3	20.83	9.66	9.60	10	6.6	13.70	1644	0.00082
300,000	22	11	24	18.66	5.33	14	15.72	1884	0.000783
350,000	19.3	9.67	15.67	14	11.4	12.67	13.8	1656	0.00059
400,000	27.5	22.17	15.17	20.67	17	13.67	19.36	2316	0.00072
450,000	24.33	19.50	18.50	22.30	17.33	23.0	20.83	2496	0.00069
500,000	34.67	23	26.67	40.33	32	27.3	30.7	3684	0.00092
550,000	35	35.3	42	40.3	32	37	36.9	4428	0.00101
600,000	37	42.3	53.67	37	47	48.7	44.2	5316	0.0011
650,000	46.3	48.67	77	60.3	52	50.3	55.7	6684	0.00129
700,000	78.67	82	83.67	83.67	85.3	80.3	82.27	9872	0.00176
750,000	107	95	105.5	104.5	125	87	103.9	12480	0.00208
800,000	122	142	172	151	157	122	144.3	17316	0.00270

The 120-in. lever used in the test of these roller bearings was selected because the pitch radius of the elevating rack on the gun carriage for which these bearings are intended has a radius of 120 in., and it will be noted from Table 1 that if the conditions obtained in the testing machine should prevail when the tipping parts were assembled on the carriage, it would only take an average of 30.7 lb. at that distance from the center of rotation to start rotation of the 500,000-lb. weight, provided this weight were perfectly balanced and the coefficient of friction were 0.00092.

As the middle bearing in this test was subjected to the full load, each of the outer bearings would carry half of this load, and as the coefficient of friction shown in Table 1 and Fig. 9, represents the coefficient of friction on the three bearings it may therefore, be assumed that the middle roller bearings would have a coefficient of friction of one-half of that in the table, and that each of the outer roller bearings would have one-fourth of the coefficient of friction as tabulated, which would bring it down to a very small figure.

Eight highly satisfactory tests were recently made of similar bearings, the results being a little better than those obtained during the test in 1919. In these eight tests the average effort on the 120-in. lever was 26.06 lb. for a load on the center bearing of 500,000 lb. which, according to the formulas used herein, would give a coefficient of friction for the three bearings of 0.0008, or for the middle bearing 0.0004, and for each of the two outer bearings, 0.0002.

While the data obtained during the test of these bearings indicated conditions beyond anticipation, it was not expected that the same conditions would materialize when these roller bearings were inserted into the trunnions of a cradle, due to the fact that in the test the supports for the roller bearings were close to each other, while in the case of a cradle, the roller bearings will be assembled to the trunnions, which are 8 ft. apart, The insertion of the gun causes a deflection which cannot be avoided, and which throws any perfectly aligned trunnion and trunnion bearings slightly out of their true axis. The fact of the matter is that when these roller bearings were inserted into the trunnions of the cradle of the 16-in. barbette carriage, with the gun mounted therein, the results obtained justified the adoption of this form of bearings to obtain flotation of the tipping parts of heavy ordnance material.

The coefficient of friction obtained with cradle and gun mounted was 0.0062, derived as follows:

$$u = \frac{rT_a}{R_cW} = \frac{0.625 \times 40 \times 620}{5 \times 500{,}000} = 0.0062$$

in which

u = coefficient of friction
r = radius of rolls
620 = the distance in inches from center of rotation to muzzle of gun
40 = the force in pounds at the muzzle required for rotation
5 = the distance in from the center of rotation to center of rolls, and
500,000 = the weight in pounds of the tipping parts.

This difference in the coefficient of friction, while considerable, is due to springing or deflection in the cradle and possibly to slight inaccuracy in obtaining perfect alignment in manufacture. Even at that, a coefficient of rolling friction of 0.0062 under such conditions is very acceptable.

To determine the power consumption and the advantage gained by the introduction of the roller bearings in the trunnions of the 16-in. carriage cradles, careful tests were made under power, as well as by hand. If plain bearings had been provided in the trunnions, it would have been impossible to obtain the results achieved, as the elevation of the gun to 65 deg. and a return to the 4-deg. loading angle form part of the cycle of the complete operation to be able to fire a 2340-lb. projectile every minute.

As an illustration: With the gun at 0-deg. elevation and the tipping parts in perfect equilibrium (the center of gravity of these parts are in the center of the trunnions), and with the *anti-friction device engaged*, that is, the rotating parts floating on the roller bearings, the effort to overcome the starting friction with the slow-motion mechanism was 19 lb., and with the fast-motion mechanism in gear, 49 lb. On the other hand, with the *anti-friction device disengaged*, in other words with the main trunnions of the cradle resting on the solid trunnion bearings, thus transferring the load to plain bearings, the effort for the slow motion was 280 lb., and for the fast gearing, 641 lb.

With the *anti-friction device engaged*, using electric power, it was possible either to elevate or to depress the 500,000 lb. through an arc of 72 deg. in $8\frac{1}{2}$ sec., whereas, operating by hand and using the slow motion, it required about 50 sec., and for the fast motion, about 35 sec. In contrast thereto, attempts to rotate by hand with the *anti-friction device disengaged* for the purpose of obtaining the time failed, as the efforts stated above were so great that it was merely possible to overcome the starting friction, and any movements of the tipping parts were difficult to discern. In other words it was practically impossible to move the piece with the anti-friction device disengaged except by the exertion of an excessive amount of electric power which taxed the motor to its extreme capacity, and at an extremely slow rate.

It has been intimated that anti-friction bearings in gun trunnions are subjected to excessive shocks, but this is not the case when bearings are floating. For instance, for the 16-in. gun and carriage under discussion, the static load on each bearing is 250,000 lb. At the instant of firing there is a powder pressure at the breech of the gun of 8,600,000 lb., and if there were no recoil, half of this load would come on each trunnion. The gun recoils 40 in., and the retarding motion is so designed that in this length of recoil there is a constant resistance of 1,600,000 lb., so that 800,000 lb. is the actual force due to the powder pressure on each trunnion. This force of 1,600,000 lb. does not come on the roller bearings which float away with the trunnions for a distance of 0.02 in. so that the brute metal of the trunnions is against the solid bearings in the side frames. At no time during firing at any elevation is the retarding force brought upon the roller bearings in the trunnions, due to the elastic medium of the spring actuating levers when fired at any elevation above 0 deg. For horizontal firing the cradle trunnions merely rock on the crutches until the small clearance is taken up and the force of recoil is then on the solid bearings.

Roller Bearings Introduced in Crank-Handle Spindle

For many years, in various ordnance mechanisms, loose bronze sleeves, provided with means for oiling, were assembled over steel handles. The operator would then grip this sleeve which would rotate around the handle, permitting the exertion of whatever effort would be required without the slipping of the grip.

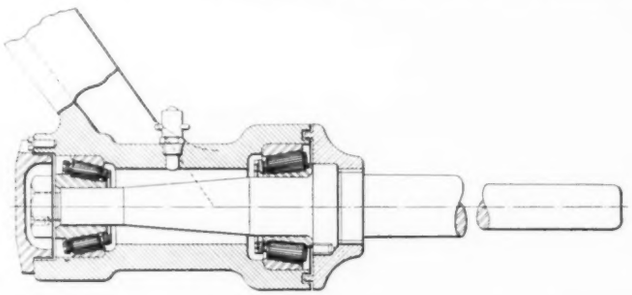

Fig. 10 Roller Bearings Applied to Handle for Hand-Operated Rotating Mechanism

When a gun carriage has been out of service for a considerable length of time, the bronze sleeve is likely to freeze to the handle and prevent rotation so that the operator's hands will slip and probably blister. For this reason roller bearings were introduced at the end of the crank handle in the housing of the crank proper, thus dispensing with the sleeve, and operators can now grip the metal handle firmly. This arrangement is shown in Fig. 10.

Elevating Screws, 14-In. Railway Mount

In the 14-in. railway mount, Model 1920, it is necessary to raise and lower the gun with the other tipping parts, as well as a portion of the top carriage, from the traveling position to the firing position and back again. In the mechanism there are two high-grade-steel screws and manganese-bronze nuts, each screw, in performing this work of raising and lowering, being subjected to a load of 140,000 lb.

Not only is the end thrust of each screw taken by conical rollers, but as the housing in which the screw and nut rest is trunnioned to permit slight rotation during the raising and lowering of the gun and appertaining parts to and from the firing position, it was necessary to introduce roller bearings at each trunnion, each of these bearings being subjected to a 70,000-lb. load.

In addition to the trunnion roller bearings, ball bearings are interposed in the vertical plane between the housing and the nut to eliminate excessive friction at the two points of application on which forces are exerted during the slight rotation of the housing.

During the raising and lowering of the gun by means of the two screws, the lower end of each screw being hinged at the bottom, a slight movement is created around the center of the hinge, for which originally plain bearings had been provided. It finally became necessary, in order to prevent the screws from bending, to introduce the roller bearings in Fig. 11. As the space for the introduction of anti-friction bearings was very limited, it was necessary to crowd in as many rollers as possible without the use of a cage, and as the movement there is very slight, amounting to only a few degrees during the operation of lowering and raising, tests demonstrated that the trouble originally experienced with plain bearings at the points in question was entirely eliminated by the introduction of these special roller bearings. Each of the roller bearings at the lower end is subjected to a load of 70,000 lb.

ROLLER THRUST BEARINGS FOR 168,000 LB.

It is also necessary to raise and lower the whole 14-in. mount so as to obtain clearance between the rails and the lower baseplate when in transit, and to lower it for firing on a permanent emplacement, or for the removal of the trucks when fired from a field emplacement. This is accomplished by means of four screws made of high-grade steel in bronze nuts, and the thrust is taken up as in the case of the top-carriage raising screws by four conical roller thrust bearings, the total load on which is 672,000 lb., or 168,000 lb. on each bearing.

These bearings were tested for the designed loads in pairs on a specially devised fixture. The coefficient of friction for the two bearings was 0.004, or 0.002 for one. A cross-section of these bearings is shown in Fig. 12. These bearings had to be made with almost mathematical precision, and accurate gages were provided by the manufacturers, and the Government also provided a special test gage for inspection.

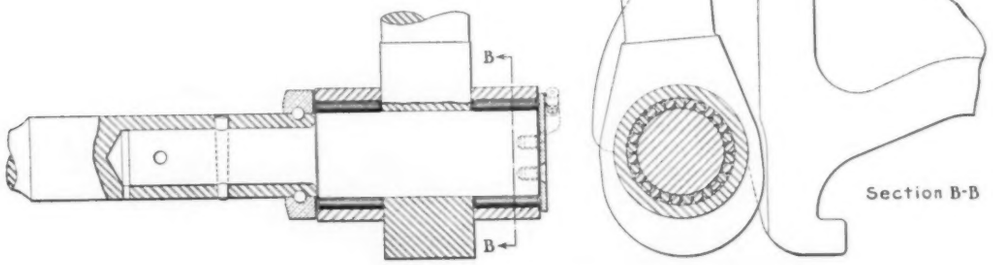

FIG. 11 ROLLER BEARING AT LOWER END OF RAISING SCREW, 14-IN. RAILWAY MOUNT

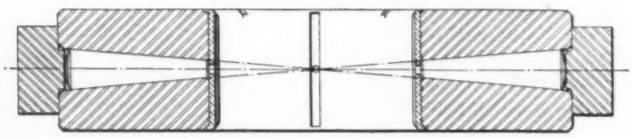

FIG. 12 CROSS-SECTION OF ROLLER THRUST BEARING TO WITHSTAND LOAD OF 168,000 LB. AT 3 R.P.M.

SPECIFICATIONS

Specifications for roller thrust bearings for mount-lifting mechanism and top-carriage raising gear for 14-in. railway mount, Model of 1920, are in part as follows:

The high-carbon steel designated on the drawings as steel W. D. 52,100, shall have the following chemical composition in percentage:

Carbon	0.91–1.10
Manganese	0.20–0.50
Phosphorus (maximum)	0.03
Sulphur (maximum)	0.03
Chromium	1.20–1.50

The scleroscope hardness as required by the drawings and between the limits specified must be obtained by the proper heat treatment, namely, for rings and races 80 to 90, and for rollers 75 to 80.

The retaining ring which is used in the roller thrust bearing for the mount-lifting mechanism, only, shall be made of bronze No. 5, in accordance with Ordnance Department, U.S.A., Metal Specifications No. 57-70A, dated July 23, 1924.

In order to insure that the bearings furnished are suitable before actual trial in the mounts, the following conditions shall be complied with:

(*a*) Each roller to be tested individually for correctness of spherical surface at large end—first by use of the inspection gages, and then by placing the spherical end against the inner surface of the thrust ring, and viewing against strong light. No light should pass.

(*b*) Test rollers for angle of taper and location of spherical end from apex of cone.

(*c*) Cross-section of rollers must be truly circular ±0.0001 in.

(*d*) Test for correctness of angle on races.

(*e*) Soundness of parts: drop test for rollers and sounding races and thrust rings.

(*f*) With all the rollers pushed together so as to touch, the clearance gap should have its sides radial, and of a magnitude at the large end equal to 0.025 in. as prescribed on the drawings.

(*g*) With rollers in place on one race, the other race should be thinly coated with prussian blue, and a test made for uniform bearing on all rollers.

(*h*) The overall thickness of the assembled bearing must be made to the prescribed dimension as shown at assembly view, namely, 1.875 $^{+0.001}_{-0.000}$ in.

(*i*) So that the Government inspector may be able to inspect, accurately, the races and rollers for the mount-lifting mechanism, the retaining rings should not be crimped by the manufacturer until after this inspection has been made, and not until after the test prescribed in the following subparagraph (*j*) has also been made at the Watertown Arsenal, and if this test is satisfactory and the bearings otherwise accepted, then the retaining rings are to be crimped in place.

(*j*) All of the completed bearings are to be tested in pairs at the Watertown Arsenal before acceptance.

(*k*) With a total pressure of 140,000 and 168,000 lb., the coefficient of friction of one bearing should not exceed 0.004 for top-carriage raising bearings and for mount-lifting bearings, respectively.

FIRING LOAD APPLIED DIRECTLY ON ANTI-FRICTION BEARINGS WITHOUT THE INTRODUCTION OF YIELDING MEDIUM

In recent designs of gun carriages for comparatively small-caliber guns, anti-friction bearings have been introduced in the trunnions and pivots, the loads due to the firing being transmitted directly on the bearings. Preliminary tests have demonstrated that the bearings thus far tried out are satisfactory.

In a recent design of a 3-in. anti-aircraft project, as well as in a design made about a year ago of the 155-mm. howitzer carriage, both of which are practically completed and will undergo proof-

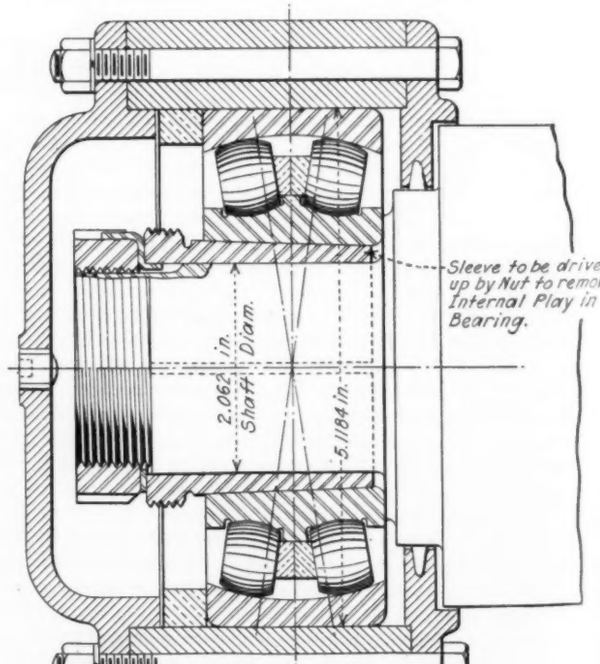

FIG. 13 SELF-ALIGNING BEARING FOR TRUNNIONS OF 3-IN. ANTI-AIRCRAFT GUN

firing very shortly, advantage was taken of anti-friction bearings at the most critical points where the stresses are most severe, and on which depend the speed by which the gun can be elevated or traversed. The difference however in the two designs, so far as the bearing question is concerned, is with reference to the kind of bearings introduced. In the 3-in. anti-aircraft project, self-aligning bearings have been specified, whereas in the 155-mm. howitzer project, straight roller bearings have been provided.

In the 3-in. project, the force required to control the recoil over its length is 18,000 lb., which brings 9000 lb. on each of the self-aligning bearings at the trunnions, and there is a reacting force of 13,400 lb. at the lower end of the pivot, which comes on one bearing.

The guaranteed capacity for 0 revolutions is 28,000 lb., which should give an ample factor of safety.

On the 155-mm. howitzer project, however, where plain roller bearings have been introduced, the forces are much greater, and to control the recoil due to the powder gases during the length of recoil, a force of 50,000 lb. is required. This brings 25,000 lb. on each of the plain roller bearings. The reacting force at the lower end of the pivot is 104,000 lb., which comes on one roller bearing, and in this design a plain roller bearing has also been introduced in the middle of the pivot, the combined load on which is the sum of the upper and lower forces, and thus amounts to 154,000 lb.

A rather neat arrangement has been provided by the manufacturer of the self-aligning bearings used on the 3-in. anti-aircraft piece to obviate any looseness or clearance whatever between the inner and outer races and the rollers. (See Fig. 13.) As this gun is controlled in elevation by instruments which are controlled from a central station or control room, the motive power of which is accurately synchronized, it is necessary to obviate all looseness between metal-to-metal working parts, in order that "follow-the-pointer" method will set the gun in elevation accurately as determined in the control room.

As manufactured, these bearings may have 0.001 in. looseness between the rollers and their surfaces, but by introducing a split bushing slightly tapered on the outside, which engages the correspondingly tapered surface of the inner diameter of the inner race, and by a screw adjustment from the trunnions, the tapered bushing is forced inward, thus expanding the inner race, and eliminating all looseness. This operation, however, must be very carefully made and only by an engineer who is familiar with this work, otherwise with too much expansion strains are set up in the parts affected, which, when the firing load is applied, may result in failures.

No such arrangement is necessary on the 155-mm. howitzer project as controlling instruments are not used with it.

A rather neat arrangement of floating roller bearings in the cradle trunnions on the 3-in. project of Model 1917M1 is shown in Fig. 14, where plain roller bearings are used. Belleville springs are introduced for a yielding medium. The static load on each bearing is about 4000 lb., whereas the force due to the firing is 15,000 lb. on each trunnion. As there is only 0.008 in. clearance under the trunnion, the two pairs of Belleville springs will yield to this amount, after which the main force will come on the solid trunnions and trunnion seats. The method of adjustment is shown clearly in the illustration.

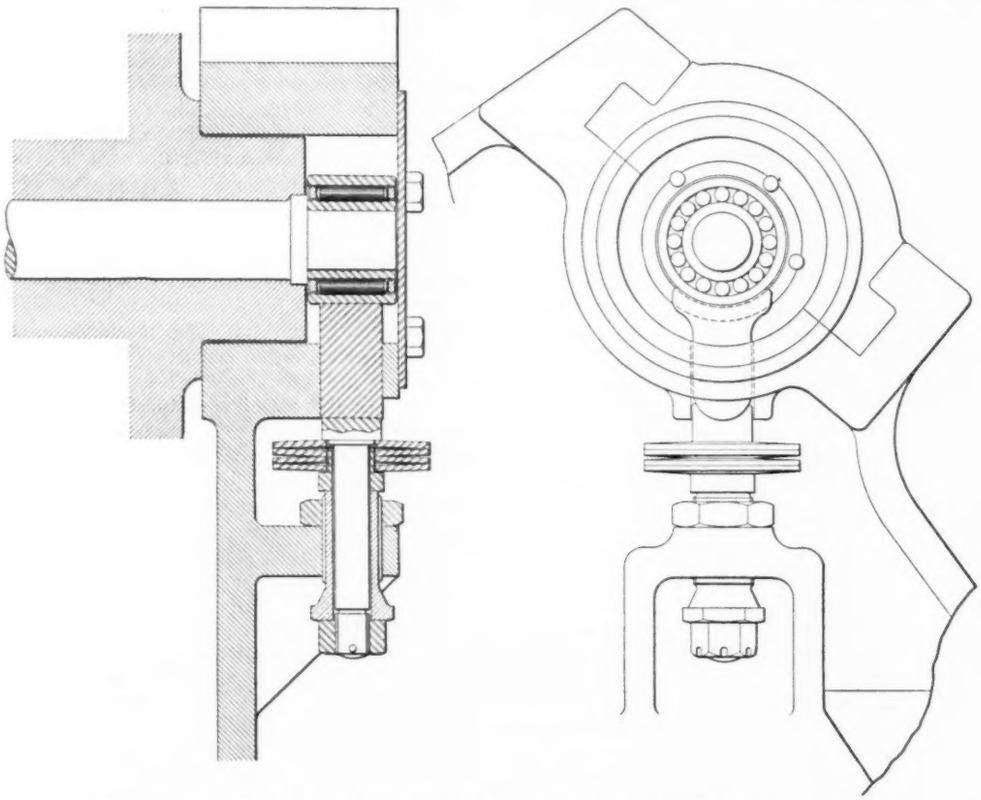

FIG. 14 ANTI-FRICTION DEVICE FOR TRUNNIONS OF 3-IN. PROJECT OF MODEL 1917M1

It is a significant fact that practically all epoch-making inventions have been due to the work of more than one man, the cotton-gin of Eli Whitney being one of the few notable exceptions. There have been two stages in the development of most great inventions. The first is related to the purely theoretical or scientific part of the work, and the second, to practical and commercial development.

Frequently men whose chief interests are centered upon scientific research make certain fundamental discoveries; then along comes the man whose natural bent lies in applying principles and elements in a practical way. The one who finally receives credit for the invention may have done little more than use what had been handed down to him by earlier scientists or inventors.

Many scientists and originators of basic ideas have not been awarded the credit due them, because the most important part of the work is to develop a practical invention that is obtainable for general use. Popular recognition is received by the inventor who makes a usable telegraph, telephone, electric light, or sewing machine, because he deals directly with the needs of the public.—*Machinery*, August, 1927, p. 902.

The Economics of Machine-Tool Replacement

Present Market Conditions and Tendencies in Machine-Tool Design—Comparison of New with Former Types of Machine Tools and Savings Effected by Replacements

By MYRON S. CURTIS,[1] PAWTUCKET, R. I.

THE ECONOMICS of machine-tool replacement is a subject that is of vital importance both to the machine-tool builder and to the machine-tool user. This is the sole excuse for this paper, for the information given will be found to be neither decidedly new nor of a radical nature.

There is no question but that the period of enormous expansion in practically every manufacturing line, and particularly in the automotive industry, which has been witnessed in the last fifteen years has ceased, at least for the present. While it is entirely possible that there may be extensive development and expansion of certain lines, which will in turn affect certain branches of the machine-tool industry, still it is extremely doubtful that we shall see any general expansion. For example, the automotive industry is beginning to realize that it must depend for its dividends upon increasing the profit per unit rather than upon increasing production. As opposed to this we find the machine-tool industry in an overexpanded condition due to the enormous demands made upon it by the growth of the automotive industry and by the conditions brought about by the World War. Also, machine tools of today are of a much more rugged nature, and are more foolproof in construction than those of a few years back, thereby extending the probable life of the machine tremendously. Again, improvements in the design of machine tools have generally increased the productive capacity from fifty to in some cases six hundred per cent, reducing the potential market. It is easy to figure that if a tool put out by a machine-tool maker today will do twice as much work as one put out by him five years ago, all other things being equal, he will only sell one half as many machines as formerly.

Outlet must be found for at least a reasonable percentage of the capacity output of the machine-tool industry. If it cannot be absorbed by expansion it necessarily follows that it must be absorbed by replacement. This, in turn, may be caused either by the development of improved methods of manufacture, that is to say, the replacement of a machine tool by one of an entirely different nature, or else by improvements in the machine tools themselves, whereby a lathe is replaced by a lathe, a milling machine by a milling machine, and so forth. The machine-tool builder has had and always will have an increased field by developing improved methods of manufacture, not only in hundreds of shops where obsolete methods of manufacture still exist, but even in the up-to-date production shops of today.

This question of machine-tool replacement is also vital to the machine-tool user. There is no doubt but that, with the keen competition now existing in all manufacturing lines, the organizations which survive will be those which have equipped themselves with the best plant and personnel. This particularly applies to industries in New England.

The tendency to cling to obsolete machinery simply because it is in good condition and is capable of doing about the same amount of work which it did when it was installed, will eventually put any concern out of business. There should be no more hesitation in scrapping an old or inefficient machine than there is in getting rid of inefficient men. As a matter of fact, the obsolete machine is a greater liability to the plant than the inefficient man. J. A. Smith, the general superintendent of the General Electric Company, which is one of the biggest users of machine tools in the country and a concern which has to meet the strongest kind of competition, says:

> I believe it is thoroughly bad for shop morale to keep a lot of superannuated machine tools standing around. They occupy valuable space that ought to be devoted to a productive machine. They tie up motors that ought to be working. If your equipment is obsolete, sell it. If you can't sell it, scrap it. It is too expensive to have around the shop.
>
> No concern equipped with obsolete tools can hope to compete these days, and the only cure for the ailment is amputation and replacement.

What makes a machine tool obsolete? Two things: first, the nature of the tool and the way it has been treated; second, the developments of the art through which the modern tool produces more than the one it supplants. In regard to the first reason, a tool may be in such shape that it is unable to produce sufficiently accurate work, or it may be that repairs are altogether too frequent, and result in excessive waste of productive time. This may be due to faulty design of the machine tool or to careless handling, particularly in regard to keeping the machine clean and oiled. A machine tool may be obsolete for the work it is performing, but may be very useful and economical on some other job. In such cases the tool should be transferred to the other work and a new tool provided for the work which is beyond the capacity of the first one. If, however, there is no job on which the tool can be economically placed, it should be immediately scrapped, as it is too costly to use.

The second reason for machine-tool obsolescence is due to the improvement in the art. The machine-tool industry has made enormous strides in the last five years. During the war and for some years previous a machine-tool builder, no matter what his product, was able to sell the capacity production of his shop, and therefore the average manufacturer was not particularly interested in making any radical changes in his product. He was concerned solely with production. Immediately after the armistice, however, conditions changed, and the market for machine tools became a buyer's market instead of a seller's market. This caused the up-to-date manufacturer to start redesigning and improving his line, so that today it is safe to say that nearly every type of machine tool built prior to 1921 is totally obsolete for production. The machine-tool builder is designing to take feeds and speeds which were unheard of even five years ago, and is taking full advantage of the developments in high-speed cutting tools. Five years ago the art of making cutting tools was far ahead of machine-tool design. Few if any machines were capable of forcing high-speed steel to the limit. Today this condition has changed and the capacity of the modern machine tool is dependent wholly upon the ability of the cutting tool to stand up. Of course, all machines built five years ago are not obsolete for all classes of work. Certain jobs are inherently too weak in themselves to withstand heavy feeds and speeds, or can be machined just so fast because of the distortion due to heat and the limits required.

Tendencies in Modern Design

It will be well at this time to point out some of the improvements in design by which these results have been brought about. There are three main tendencies:

1. Increased power and rigidity together with the correlative ability to withstand abuse
2. Increased convenience for the operator
3. More foolproof construction.

Some of the tendencies toward increased power and rigidity follow: More and better-placed material is used in beds, gear boxes, carriages, etc. Thirty years ago most machine tools, especially those of British manufacture, were extremely heavy. Gradually the lines were refined and excess material was done away with. Then came the introduction of high-speed steel, and nearly every machine tool on the market proved to be too light to withstand the heavy duty imposed. The metal which was removed has been gradually put back, especially since the importance of freedom of vibration to cutting-tool life has been learned. Today, machines are made not only strong enough to withstand the strains imposed,

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[1] Potter & Johnson Machine Co.

For presentation at the First National Meeting of the A.S.M.E. Machine Shop Practice Division and the New Haven Machine Tool Exhibition, Mason Laboratory, Yale University, New Haven, Conn., September 6–9, 1927.

but also heavy enough to absorb all vibration at the cutting edge of the tool.

There is a definite tendency toward the use of alloy steels for shafts, gears, etc. This is a direct result of knowledge gained from the automotive industry, and today every good machine tool has its high-duty gears and shafts made of heat-treated alloy steel. Another direct result of the influence of the automotive industry is the use of anti-friction bearings for all fast-running high-duty shafts. A more recent development has been the use of anti-friction bearings for spindles of lathes and milling machines. Certain light high-speed machines, such as woodworking machinery, drill presses, grinders, etc., have long employed anti-friction bearings for spindle mountings but it is only lately that successful applications of anti-friction bearings to high-duty spindles such as those of lathes and milling machines have been accomplished. This is a long step forward, resulting as it does in increased accuracy, lessened friction, and longer life of bearings.

Increased convenience of operation has been accomplished by well-thought-out design in the grouping of levers, the accessibility of change gears and cams, etc., all of which cut down the setting-up time materially, and by reducing fatigue make it possible for the operator to produce more work in a given time.

More foolproof construction is absolutely necessary today, as the class of help operating machine tools under production conditions has definitely changed to unskilled labor. A production tool is no longer operated by a mechanic—a man who understands its various functions, and who takes pride in keeping his machine running smoothly and efficiently. This type of man can no longer be found in sufficient numbers to operate our shops. The use of interlocking levers, safety devices such as slip frictions and shear pins, and, on some of the simpler tools, hydraulic feeding, mechanisms, is therefore noted. The matter of oiling has also received considerable attention. Five years ago most machine tools were oiled by the old-fashioned oil can and the tool with any well-thought-out system of oiling was an exception. Today are to be noted the use of enclosed gear boxes running in oil, mechanical oiling systems such as have been for a long time used on engines, unit oiling systems, usually with a sight-feed drip whereby one or two oil reservoirs oil the whole machine, and more recently, the development of the one-shot oiling system.

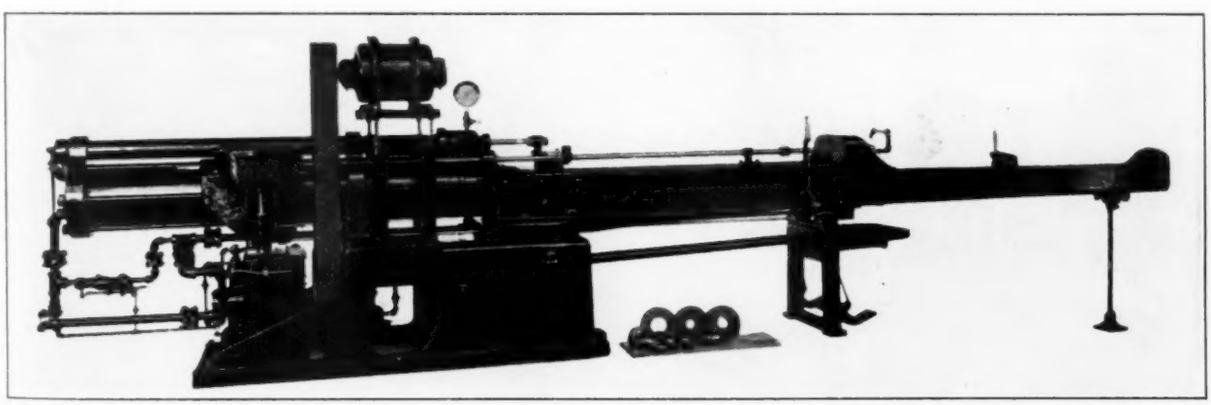

FIG. 1 HYDRAULIC BROACHING MACHINE

These three general developments, namely, increased power and rigidity, increased convenience for the operator, and foolproof construction, have resulted in an enormous increase in the productive capacity of machine tools, and increase in production hours because of freedom from breakdowns.

COMPARISONS OF PRESENT AND FORMER MACHINE TOOLS

In the standard type of screw-feed broaching machine the broach is pulled through the work by a rotating nut and non-rotating screw.

Fig. 1 shows the latest developments in hydraulic broaching machines. The crosshead and the draw head for adjusting the broaching tools are similar to those previously used in the screw-type machine. However, the crosshead is pulled by a piston rod instead of a screw, the piston rod being attached to a piston in an 8-in.-diameter hydraulic cylinder. This hydraulic cylinder is connected with a variable-stroke pump, the displacement of which is controlled during the pulling and return strokes of the broach by tappets operated at the two ends of the stroke. These tappets operate the pump valve so as to give a slow feed and a quick return, and the feed can also be adjusted from zero to maximum by varying the stroke of the pump, thus allowing the best broaching speed to be obtained. In the pipe line is a release valve which may be set at any predetermined load. If for any reason the pressure rises above this amount, the valve operates to bypass the pump, relieving the pulling force on the broach to zero. With this safety attachment a serious breakdown is impossible, and the feed may be set near the capacity of the broach without fear of overload if the broach becomes dull or if extra-hard subjects are met with.

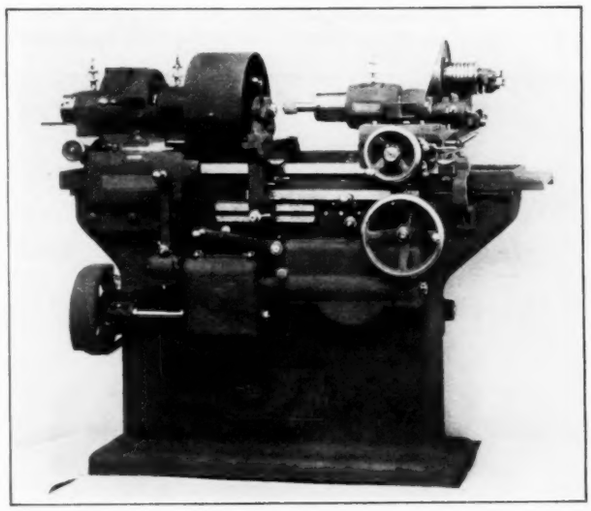

FIG. 2 INTERNAL GRINDER

The great increase in production obtained by the hydraulic method is due to elimination of the great power loss from the friction of the screw and nut, which makes it impossible to run a heavily loaded screw broach at more than 4 or 5 ft. per min. cutting speed. Experience with the hydraulic method has proved that the hardest commercial material can readily be broached at a cutting speed of not lower than 12 ft. per min. while low-carbon steels are frequently broached at 25 to 30 ft. per min., an increase of from 250 to 600 per cent. The adaptation of the hydraulic pulling mechanism has also permitted broaches to be designed to take a good-sized chip, thus allowing a job to be done with one broach which formerly required two or three. The efficiency of the hydraulic broach is also about $4^1/_2$ times the efficiency of the screw broach.

A standard engine lathe of approximately five years ago was equipped with cone-driven backgeared headstock, countershaft shipping, and hand change-feed gears at the head end.

A recent model of this lathe has a single-pulley drive, ball-bearing headstock running in oil, and the speed-change levers conveniently mounted on the headstock. The feed gearing is changed by a tumbler gear and cone, these gears being made of steel. The operating lever for starting, stopping, braking, and reversing the spindle is placed so that it travels with the carriage, thus always being within reach of the operator. The longitudinal feed is provided with multiple stops which can be set so as to automatically trip the feed at any desired position, thus enabling distances between shoulders to be duplicated without the use of measuring instruments. Multiple-diameter stops mounted on the cross feed screw allow diameters to be readily determined without the use of calipers. This machine is also equipped with a pan, pump, and tubing for applying cutting compound to the tool, thus materially

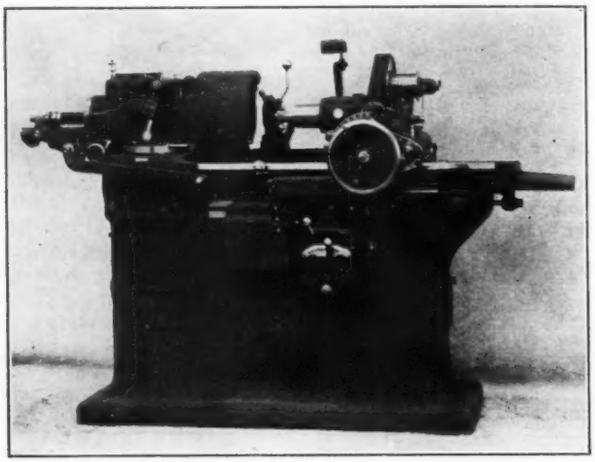

FIG. 3 PRESENT DESIGN OF INTERNAL GRINDER

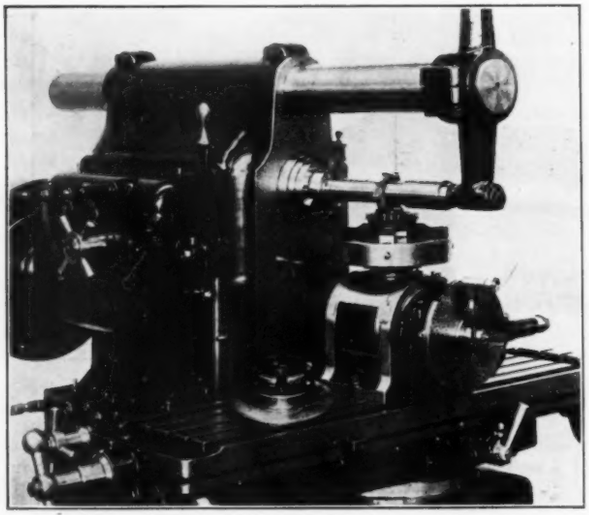

FIG. 4 MILLING MACHINE

lengthening the life of the tool and permitting increased cutting speeds. Although every one knows that higher cutting speeds and longer tool life are gained by the use of coolant, it is safe to say that at least 75 per cent of the lathes operated in New England shops are cutting without the use of compound. These various improvements in design have so increased the productive capacity of this lathe that the makers claim that a time saving of from 25 to 75 per cent may be made as compared to the ordinary engine lathes.

In a former type of flat-turret lathe, the head was of the cone type with friction backgears. There was but one carriage, having power longitudinal and cross feeds which could be changed at the feed box on the head end of the machine, the feed reverse also being contained in this box. All changes were made through the shifting of drive keys, and to engage the longitudinal or cross feed in the apron, it was necessary to engage a worm with a wormwheel. The machine had no rapid traverse to the carriage and no centralized control.

In the present model of the same machine, the geared head has single-pulley drive, hardened alloy-steel gears running in oil, and automatic disengagement of the multiple-disk driving clutch when the gears are shifted, offering not only a practically instantaneous change, but also a foolproof construction. A cross turret has been added, and all feed changes are incorporated in the aprons, allowing instantaneous shifting of feeds without walking to the end of the machine to shift tumbler gears. These feed gears are hardened, run in a bath of oil, and are mounted on square shafts running in ball bearings. A rapid power traverse in either direction is accomplished by a lever located on the apron. The operation of this lever automatically disengages the feed and the turnstile, another instance of convenience and foolproof construction. The added features in this machine have resulted in increased production of from 50 to 100 per cent, some users paying for the machine in six months by increased production.

Fig. 2 is an internal grinder of a few years back. It would seem from a glance that this machine was about the latest word in convenience, having as it does all levers centrally located, a quick-change gear box giving three rates of table travel for each work speed, automatic wheel guard, etc.

Fig. 3 shows the present design of this machine. The table

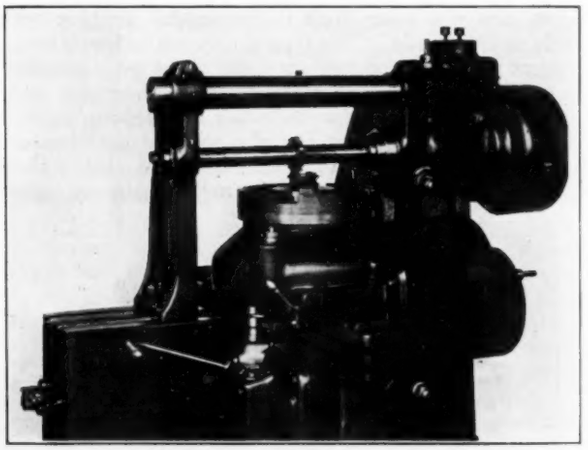

FIG. 5 PRESENT DESIGN OF MILLING MACHINE

is hydraulically driven, giving unlimited speeds, quick traverse for bringing the wheel to and from the work, and complete control of speeds and direction of movement at all times. An automatic short-stroke dog and a convenient wheel-truing device allow the operator to true his wheel just before finishing the work and are of great assistance in obtaining production and finish. The water starts and stops simultaneously with the work. Hand and automatic feed pawls for the wheel are provided. These improvements and others result in the following increased production times:

Hardened steel bushings, $^3/_4$-in. hole, $1^3/_4$ in. long, 0.0005-in. limit, increase from 45 to 100 per hr.

Hardened gear, $1^7/_{16}$-in. hole, $1^9/_{16}$ in. long, 0.0005-in. limit, increase from 22 to 70 per hr.

Bronze bushing, $1^5/_8$-in. hole, 2 in. long, 0.001-in. limit, increase from 18 to 60 per hr.

Ball race, $1^3/_{16}$-in. hole, $^4/_{16}$ in. long, 0.0005-in. limit, increase from 50 to 140 per hr.

Note that the increase in production ranges from 100 to 350 per cent.

An interesting comparison showing gain in production by the use of a modern-type milling machine is shown in Figs. 4 and 5.

Fig. 4 illustrates the old method of milling clutch teeth. The machine is of the old knee-and-column type with old-style round over arm, and tumbler construction for the drive. The time per piece was 7.65 min.

Fig. 5 illustrates the present method of machining the same piece. The machine used is a fixed-bed-type automatic milling

machine. All operations, including the indexing of the fixtures, are automatic, and all that the operator has to do is to remove and load the work and start the machine. The time per piece is 3.58 min., less than half the time on the old-type machine, and due to the automatic features, one man can run several machines.

Fig. 6 is a model 6A automatic chucking machine. The spindle gearing is located in the bed of the machine, all shafts run in plain bearings, and none of the gears runs in oil. The cross-slide is fed by rack and pinion from the cam drum, and the turret drum is of cast iron with inserted hardened-steel strips. This model was standard five years ago, and is still satisfactory for certain classes of light work, but has, however, been superseded for heavy production.

Fig. 7 is the new model 5D chucking machine. Some of the improvements in this model are as follows: an all-geared headstock, all gearing and shafting being of chrome-nickel steel hardened; all shafts running in anti-friction bearings, and the spindle itself running in anti-friction bearings. All high-speed gears are helical, making a practically noiseless gear box. The bed of the machine

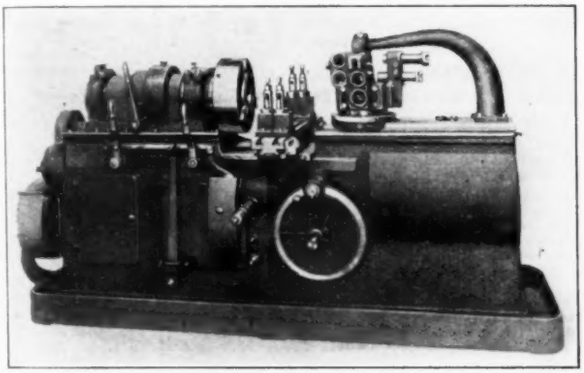

FIG. 6 AUTOMATIC CHUCKING MACHINE, MODEL 6A

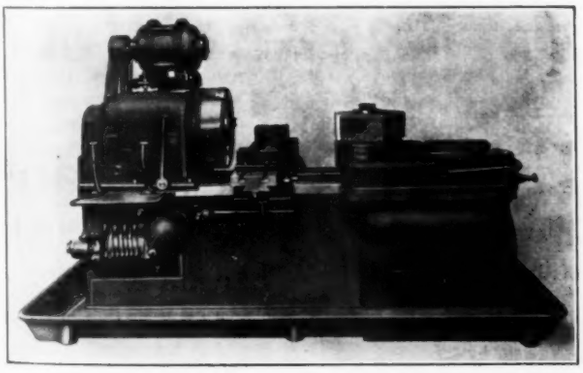

FIG. 7 AUTOMATIC CHUCKING MACHINE, MODEL 5D

has been strengthened throughout and is provided with hardened-steel ways ground in place in absolute alignment to the spindle. The turret slide is provided with hardened-steel bearing surfaces, and has been increased in size and strength. The turret seating has been greatly increased in diameter and is provided with a clamping device which does away with the old-style overhead arm. The turret cam drum has been changed from a cast-iron drum with steel strips bolted on, to a solid steel forging with the cam path milled from the solid and the whole drum case-hardened. The cross-slide is driven directly from its cam drum, and both the turret and cross-slide cam rolls are ball-bearing mounted. The feed mechanism has been simplified and at the same time improved so that any particular feed may be automatically obtained. The automatic changes of feeds and speeds are instantaneously operated by power, making it possible not only to drop from a high to a lower cutting speed, but also to jump from a low to a higher speed. The advantage of this improvement in doing long facing cuts is obvious. Besides being provided with safety couplings, the machine is oiled by a unit system.

Some of the results of these improvements have been startling, to say the least. Whereas a 10-hp. motor drove the first machine to capacity, it has been possible to put 48 hp. into the later machine without doing anything but stall the motor, and a number of machines are regularly using 25 hp. This is in spite of the fact that the anti-friction-bearing headstock shows an increased efficiency over the old-type plain-bearing head of from 30 to 50 per cent. Increase in production on this machine over the earlier machine has been anywhere from 50 to 300 per cent.

SAVINGS BY REPLACEMENTS

It is very apparent from the foregoing comparisons that the machine tool of today is incomparably more efficient than that of five years ago. There are, however, other elements which enter into the economics of replacing a machine tool besides the simple one of increased production.

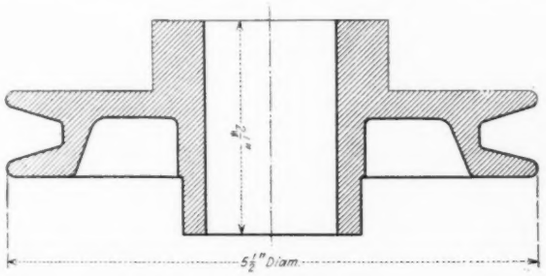

FIG. 8 CAST-IRON FAN PULLEY

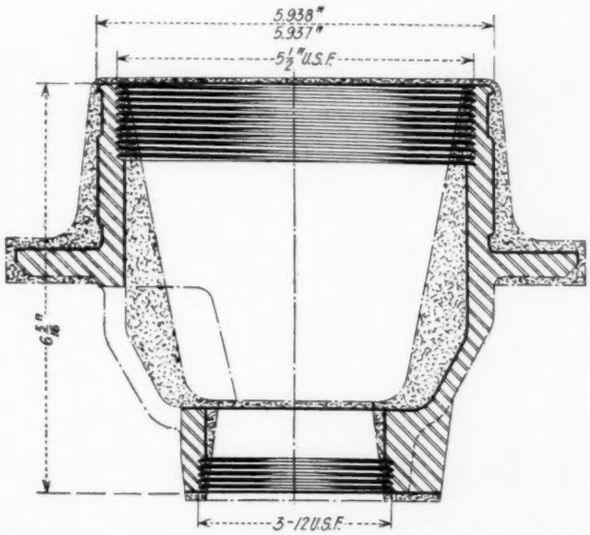

FIG. 9 FORGED DIFFERENTIAL HOUSING

The figure desired for comparison is the operating cost per hour, which consists of the prorated annual charges plus labor plus power. These annual charges take into consideration depreciation; the average interest on the cost of the machine minus the interest earned by depreciation reserve; rent; repairs; and maintenance, such as oil, cutting compound, tools, etc.

The cost of the machine installed is equal to the cost of the new machine installed less the salvage value of the machine replaced. As has been stated before, this may be anything from scrap value to the book value of the machine if applied to some other job.

A direct comparison between the operating costs of the two automatic chucking machines follows.

Tables 1 and 2 compare the two working on a cast-iron fan pulley as shown in Fig. 8. Tables 3 and 4 give a comparison on the 0.35-carbon-steel forged differential housing which is shown in Fig. 9.

It will be noted in Table 2 that the saving per piece amounts to 50 per cent and that the saving per hour to $0.72, thus giving a saving per year of $2260. This particular piece is not one of the best for purposes of comparison, as the material of the work makes

it impossible to push the machine to anything like capacity. The 6A machine does not do the grooving operation, this being done on another machine, the operating cost of which should really enter into the above comparison.

In Table 4 the saving per piece amounts to $0.265 or 59 per cent, the saving per hour $1.03, and the saving per year $3090. In the first case with the fan pulley, the machine will pay for itself in a little over two years, and in the second case, in less than two years. This plainly shows that it is economically unsound to use the old-type machine where such a saving can be accomplished.

In closing, the author wishes to acknowledge his indebtedness to Norman R. Earle of the Potter & Johnston Machine Co., for aid and advice in preparing this paper. He also wishes to acknowledge information kindly supplied by the Oilgear Co., the Lodge & Shipley Machine Tool Co., the Acme Machine Tool Co., the Cincinnati Milling Machine Co., and the Heald Machine Co.

TABLE 1

Machine: 6A automatic
Subject: Cast-iron fan pulley
Production: 10 pieces per hour
Cost of machine and tools, $3700

Annual charges	
Depreciation (10-year life)	$370.00
Average interest	122.10
Rent (same as 5D)	
Repairs	60.00
Maintenance	250.00
Total	$802.10
Operating cost per hour (250 hours per month)	
Prorated annual charges	$ 0.27
Labor (1 man operating 3 machines)	0.25
Power	0.07
	$ 0.59

$$\text{Cost per piece } \frac{0.59}{10} = \$0.059$$

TABLE 2

Machine: 5D automatic
Subject: Cast-iron fan pulley
Production: 24 pieces per hour
Cost of machine and tools, $5300 — $600 = $4700

Annual charges,	
Depreciation (10-year life)	$ 470.00
Average interest	155.10
Rent (same as 6A)	
Repairs	60.00
Maintenance	350.00
Total	$1035.00
Operating cost per hour	
Prorated annual charges	$ 0.35
Labor (1 man operating 3 machines)	0.25
Power	0.10
	$ 0.70

$$\text{Cost per piece } = \frac{0.70}{24} = \$0.029$$

Saving per piece $0.059 — $0.029 = $0.03 or 50 per cent

Cost per hour for 24 pieces 6A,	= 1.42
5D	= 0.70
Saving per hour	$ 0.72
Saving per year	$2260.00

TABLE 3

Machine: 6A automatic
Subject: 0.35 carbon forged-steel differential housing
Production: 1.33 pieces per hour
Cost of machine and tools, $4450

Annual charges	
Depreciation (10-year life)	$445.00
Average interest	146.85
Rent (same floor space as 5D)	
Repairs	60.00
Maintenance	290.00
Total	$941.85
Operating cost per hour	
Prorated annual charges	$ 0.31
Labor (1 man operating 4 machines)	0.19
Power	0.09
	$ 0.59

$$\text{Cost per piece } = \frac{0.59}{1.3} = \$0.45$$

TABLE 4

Machine: 5D automatic
Subject: 0.35 carbon forged-steel differential housing
Production: 4 pieces per hour
Cost of machine and tools, $6050 — $600 = $5450

Annual charges	
Depreciation (10-year life)	$ 545.00
Average interest	179.00
Rent (same floor space as 6A)	
Repairs	60.00
Maintenance	400.00
Total	$1184.85
Operating cost per hour	
Prorated annual charges	$ 0.40
Labor (1 man operating 4 machines)	0.19
Power	0.15
	$ 0.74

$$\text{Cost per piece } = \frac{0.74}{4} = \$0.185$$

Saving per piece $0.45 — $0.185 = $ 0.265 or 59 per cent

Cost per hour, 4 pieces, 6A	$ 1.77
Cost per hour, 4 pieces, 5D	$ 0.74
Saving per hour	$ 1.03
Saving per year	$3090.00

Shop-Equipment Policies in Representative Plants

Reasons for Discarding Equipment—Time During Which New Equipment Must Pay for Itself—Methods of Buying and Discarding—Faults of Machine Tools—Methods of Drive—Records

BY L. C. MORROW,[1] NEW YORK, N. Y.

THE TERM "shop equipment" in the metal-working industries properly includes all of the equipment used within the shop; machines, motors, conveyors, small tools, hand tools, transmission units, and so on. It is obviously impossible to treat of each kind of equipment in a paper that will not be unduly long, except as the principles laid down for one class may be applied to the others. It is with machine tools, primarily, that every metal-working shop is concerned, and therefore it is with keeping machine tools up to date that this paper deals.

How big is the machine-tool industry? What is its economic importance? The answers to these two questions will indicate the position that equipment policies should occupy in the affairs of users and builders.

The answer to the first question, "How big is the machine-tool industry?" is taken from the United States census of manufactures.

The census gives certain figures for the value of machine tools, and metal-working machinery produced during 1919, 1921, 1923, and 1925 as follows:

	1919	1921
"So-called" machine tools	$212,400,158	$ 67,782,232
Machine tools by "other" establishments	*	1,524,926
Metal-working machinery	57,541,482	19,287,572
Maximum, all products	$269,941,640	$ 88,794,730
	1923	1925
"So-called" machine tools	$136,871,096	$148,598,285
Machine tools by "other" establishments	3,787,527	**
Metal-working machinery	56,817,437	47,352,746
Maximum, all products	$197,476,060	$195,951,031

For more conservative figures, deduct the items which are not complete machine tools or metal-working machines:

	1919	1921
"All other products"	$ 32,652,932	$ 7,319,211
"Parts and attachments"	*	8,936,547
"Portable tools"	10,907,928	4,480,611
	$ 43,560,860	$ 20,736,369

[1] Managing Editor, *American Machinist*, Chairman, Machine Shop Practice Division, A.S.M.E.

For presentation at the First National Meeting of the A.S.M.E. Machine Shop Practice Division and the New Haven Machine Tool Exhibition, Mason Laboratory, Yale University, New Haven, Conn., September 6–9, 1927.

	1923	1925
"All other products"	$ 8,571,124	$ 24,946,320
"Parts and attachments"	25,397,185	32,192,602
"Portable tools"	9,312,814	11,896,325
	$ 43,281,125	$ 69,035,247

* Not given.
** Included in above.

Minimum, complete machines only, $226,380,780 in 1919; $68,058,361 in 1921; $154,194,937 in 1923; and $126,915,784 in 1925.

The minimum figures represent an unknown number of machines, but one subdivision of "machine tools," valued at $137,525,963 in 1919; $41,506,657 in 1921; $70,717,797 in 1923; and $58,334,175 in 1925;[2] represents the following numbers of machines: 163,892 in 1919; 56,675 in 1921; 68,836 in 1923; and 38,855 in 1925. The average value at factory per machine was $840 in 1919; $733 in 1921; $1030 in 1923; and $1506 in 1925.

A word of caution must be said with respect to the average value. It should not be construed that it is comparable from year to year, nor can it be significant as an average price of a machine tool, because lathes, milling machines, grinders, hack saws, etc., of widely different values are produced in different proportions in different years.

However, the average value, being large (about 1000), shows rather conclusively that no portable and small tools are included as machine tools, and tends to confirm the reasonableness of the figures.

The economic importance of the machine-tool industry cannot be measured by the size of the industry. It is the bit of yeast in the bread that is important—without it the bread would not rise. In answering the second question, "What is the economic importance of the machine-tool industry?" it is enough to say that back of all labor-saving machinery, back of the economical production of every mechanical necessity or labor-saving machine in the world, stand the machine tools that made them possible. Without them we could have no industry as it now exists. There could be no factories for the making of either necessities or luxuries.

Since 1914, while the population of the United States has been increasing 18 per cent, the productivity of the nation has increased 35 per cent, a rate almost double.

The railroads today are carrying 20 per cent more freight than in 1914 with practically the same number of employees.

The farms are producing 35 per cent more in volume of crops with an actual decrease in the number of farmers.

In these thirteen years, the automobile industry has multiplied almost eightfold in the number of cars built per year and over sixfold in the total annual value of the product, yet with a steady decrease in the hours of human labor per car. Whereas in 1914, the average medium-priced car required 1260 hours of labor, today it requires but 220 hours. Yet with all this decrease of human labor, the quality of workmanship per car has steadily increased.

Seven years ago, one man could handle only 800 tons of pig iron per year. Today his capacity is 1200 tons a year. Eight years ago a pair of shoes required one hour and forty minutes of human labor. Today a pair of shoes requires but 54 minutes.

The machine has brought about this advance everywhere in national productivity, this decrease everywhere in the number of human-hours or human-minutes per piece, per ton, per dozen, per acre.

In the past thirteen years, over 6500 new metal-working machines and tools have appeared on the market—improvements on old types, new developments, new creations of mechanical genius—all designed to increase output and accuracy, and to reduce upkeep and labor.

It is gratifying that there is a growing recognition of the importance of the machine-tool industry in the economic scheme. An indication of this increasing recognition is the thoroughness with which many large users of machine tools are studying their equipment problems from the engineering and profit points of view. It is true that even in some of the larger plants there still exist hit-and-miss methods of discarding and buying equipment, and that education to substitute definite policies is needed. Likewise in the plants of medium size and in the small shops ideas are not so well defined as they should be. There is a duty to be performed on the part of the machine-tool builders, on the part of the machine-tool salesman, and, perforce, on the part of the educators of the machinery industries, to supply the deficiency.

[2] Returns incomplete.

The subject of keeping the machine-tool equipment up to date falls very naturally into these subdivisions:

Reasons for discarding equipment
Time during which new equipment must pay for itself from earnings
Methods of buying
Disposition of discarded equipment
Faults of machine tools
Method of drive
Single-purpose vs. standard machines
Machine-tool records, especially those of repairs
Importance of the human equation in equipment policies.

Reasons for Discarding Equipment

Equipment is discarded because it is worn out or because it is obsolete. Almost all machine tools are made up of several castings proportionately large, with smaller parts of other materials. There is seldom a great amount of wear on the castings, and the deterioration of cast iron is not rapid. Of the parts made of other materials, new ones can be made or bought. Inasmuch as wear upon all parts is seldom uniform, it would seem that if each part were replaced as it became worn the machine would never wear out. Experience proves, however, that there is a relation between the cost of repairs and the cost of new machines, that, if determined accurately, will indicate when expenses for repairs are no longer justified. There are to be taken into consideration the losses due to the non-productiveness of the machines while in course of repair. The repair cost is being maintained by some of the largest users of machine tools. If the plan should be adopted universally much of the ancient equipment now in use would be withdrawn from active service. Moreover, the records of the costs of repairs, used with the records of initial costs, would enable all users of equipment to arrive at sound rates of depreciation.

Obsolescence is brought about by several influences. They are:

Improvements in the design of machine tools
Increased output requirements
Changes in the design of the product of the user
Elimination of uneconomical manufacturing operations
Changes in the methods of manufacture of the product of the user
The effect upon the investment in materials in process
The effect upon floor space
The effect upon power consumption.

One manufacturer gives the definition of obsolescence by saying that a machine is obsolete when it will no longer pay the dividends obtainable from some other machine. Another, that obsolescence as applied to productive machine tools is the result of the elimination of uneconomical manufacturing operations. Still another, that a machine tool is made obsolete by the development of the art through which the modern tool produces more than the one it supplants.

Some of the reasons that have been given for discarding equipment and for buying new are:

Repairs too frequent
The new machine is a better investment
Worn out
Too light for heavy duty
Machine does away with hand labor
Cannot afford to waste the time of a high-priced mechanic on a low-production machine
Difficulty of keeping operator interested in old machine
Cost per productive hour of operation shows that machine is not economical for the production loaded on it
There is a constant pressure from the customer for lower prices on the product—a pressure that must be met by lower costs of production
To secure maximum output with the greatest possible protection of the employee's health and life

To secure increased production
To secure better quality
To reduce the cost of manufacture
To reduce the items of expense that make up the cost per hour
For manufacturing a new line of apparatus
To reduce the cost of direct labor
To reduce the investment in materials in process
To eliminate the necessity for highly skilled operators
To reduce the power consumption
Changes in the design of product
Changes in the methods of manufacture
Availability of machines of new design
To get more out of the dollar invested.

TIME ALLOTTED MACHINE TO PAY FOR ITSELF

There arises the question, "How much better than the old must a new machine be?" From the data available it seems that the consensus of opinion is that it must be very much better indeed. The automotive industry is very strongly inclined toward the belief that the new machine must be so much better that it will pay for itself from increased earnings within one year. Other manufacturers, whose products include tractors, ball bearings, automobile starting, lighting, and ignition systems, universal joints, vacuum sweepers, roller bearings, cash registers, and machine tools, vary from a limit of one year to a limit of several years, say, four or five. A railroad repair shop allows as much as six or seven years. One or two refuse to set a limit, taking the stand that each purchase must be made strictly upon the merits of the case. The principal argument advanced to substantiate the claim that one year is the proper limit, is that there are yearly changes in the product manufactured that are likely to make much equipment worthless. No doubt that argument carries weight when special machinery is being considered. So-called standard machines should have more in their favor, especially in view of the fact that the volume of sales of machine tools does not indicate that any immense number of standard tools are written off the books within one year or anything like that period.

Surmise aside, existing conditions call for continual and marked advance in the design of machine tools. Certain it is that the users of machine tools have given the matter serious consideration. They have at times reduced their calculations to formulas. For example, one manufacturer uses a formula to say that the number of months in which a piece of equipment will pay for itself is equal to the total of expenditures for the new equipment divided by the total of savings per month. Stated more elaborately, it says that *the number of months in which the equipment will pay for itself* equals *the cost of the new equipment installed* plus *the cost of tooling the new equipment* plus *the cost of interest for X years at 6 per cent* (*X* equaling the number of years determined upon as the maximum time during which the equipment must pay for itself) plus *the cost of depreciation for X years at 10 per cent* plus *the book value of the displaced equipment*, that sum divided by the difference between *the existing rate (or cost) per piece* and *the estimated rate per piece on the proposed new equipment* multiplied by *the number of pieces to be produced per day by the proposed equipment*, multiplied in turn by *the number of working days per month*, to which product is added *the savings in overhead per month*.

In that formula it is considered that the savings are made up of productive labor, and that if the expense of productive labor is cut in half, the percentage of overhead to productive labor is increased 10 per cent. This conclusion is reached as a result of cost determinations, and there is no doubt that it applies in the plant using the formula.

Another manufacturer uses practically the same formula, except that he determines his change in overhead from a "burden control record" that shows direct labor charges; direct burden charges (under which there are 14 subdivisions); indirect burden charges (under which there are 8 subdivisions); and fixed charges (under which there are 6 subdivisions).

These two examples are cited to show to what extent some users of shop equipment have gone to determine on an engineering basis their policies of discarding and purchasing equipment. For the most part they have been left to do these things for themselves, although it might seem quite logical to believe that such definite methods of determining the value of new equipment should have been worked out and presented as sales arguments by the machine-tool builders.

BUYING METHODS

There is a definite movement away from the selection of machine tools and equipment of like importance by the purchasing agent or purchasing department. There are exceptions where the purchasing agent is a man of engineering training or caliber who could properly be called an equipment engineer. However, in almost all plants of appreciable size, the formal order is issued by the purchasing department, which is responsible also for follow-up. Many times the requests for quotations are written and signed by the purchasing departments. In some plants, where the purchasing department has nothing to do with the acquisition of equipment except the clerical work, it is nevertheless necessary for salesmen to make their overtures to that department, and upon all visits to go through the formality of gaining admittance by applying first to the purchasing agent.

No fault should be found with the arrangement just described where it exists. Each plant has its own problems to solve in taking care of visitors. Where there are many of them some routine must be followed in the interests of the seller and his time as well as the buyer and his time.

Some of the methods of buying with which the author has become acquainted are, in brief, these:

Plant No. 1. The shop superintendents and master mechanics make their recommendations annually at a stated interval before the equipment budget is made up. The supervisor of equipment passes on the recommendations. The financial man of the organization authorizes the procuring of data. The purchasing agent obtains proposals. The machine-tool committee selects.

Plant No. 2. The superintendents of individual plants, who are responsible for their own equipment, ask for it as they need it. Their requests are sent to the plant managers, of whom there is one for every three or four plants. The plant managers act upon the requests, and send those considered favorably to the general works manager, who authorizes or rejects. An equipment engineer studies all of the requests sent to the general works manager and advises him.

Plant No. 3. Recommendations originate with the time-study department. They are approved by the head of that department, by the production manager, and by the factory manager. The equipment is bought on guaranteed production.

Plant No. 4. Requests originate with the foremen. They are investigated by the research department and approved by the factory manager. The purchasing department prepares the order, issues it, and does the follow-up work.

Plant No. 5. Demonstrators recommend that certain machines be bought. Recommendations also originate with machine-tool supervisors, who make a physical review every three months and report through their superintendents on equipment needed for greater production, to replace less suitable equipment, or to replace worn-out equipment. Action is then taken by the director of works equipment.

Plant No. 6. Foremen make recommendations to the production manager. All details of proposals and quotations are handled by the purchasing department. All salesmen are dealt with through the purchasing department.

Plant No. 7. The heads of the factory engineering, tool-equipment, and metallurgical departments make recommendations for the approval of the purchase of equipment to an operating vice-president. Foremen are consulted by those heads on problems of great detail. Details of ordering and following up are carried on by the purchasing department. Equipment is bought on trial.

Plant No. 8. The men who control the acquisition of equipment are the superintendent, supervisors, efficiency engineers, foremen, and job foremen. Any one of these men has the privilege of requesting shop equipment to improve method or product, reduce cost, or conserve floor space. All requests are studied by the efficiency-engineering department. The purchasing department obtains proposals and quotations. Formal order is made by the efficiency-engineering department. Purchasing department follows up.

Plant No. 9. Any one in the organization has the privilege of recommending the acquisition of equipment. Every recommendation goes first to the "plant committee," made up of leading foremen and superintendents and presided over by the general manufacturing superintendent. Recommendations of this committee go to the "manufacturing committee," made up of the heads of all departments, including purchasing and engineering. The committee's decisions are referred to the board of directors for approval or rejection.

Plant No. 10. The production, manufacturing, and methods and tools departments have the privilege of requesting equipment. The works manager decides upon the machines to buy. The purchasing department issues the formal order. In investigating equipment the mechanical man looks to the mechanical details. The purchasing agent looks to the purchasing details. Visiting engineering representatives of manufacturers talk to the foreman, superintendent, or works manager.

Plant No. 11. Equipment specialists determine the need for new machinery, development engineers work out new methods of manufacture, and standardization engineers have charge of the replacement of obsolete and worn-out production equipment. The duties of the standardization engineers include the development of machine specifications, assistance to and coöperation with machine-tool builders, and the development of new models of standard types of production equipment.

Plant No. 12. Orders for new and replacement equipment originate in the master-mechanic's division. They are approved by the superintendent of production. Purchasing details are cared for by the purchasing department. The master-mechanic's division is responsible for obtaining deliveries.

Plant No. 13. When machine foreman and department foreman agree that replacement is necessary, they consult the tool supervisor. When the three agree, they consult the superintendent, who makes the decision. Foremen may suggest the make of machine wanted. The tool supervisor issues requisitions, which pass through the hands of the division superintendent, general superintendent, and works manager. The purchasing agent issues the orders.

In connection with the methods of buying, it is of more than passing interest to know what are the sources of the information required by users of machine tools to enable them to keep pace with developments. In the contacts that the author has had he has found an almost unanimous agreement upon these sources:

The new-equipment sections of the technical press
The advertisements of the technical press
Machine-tool salesmen
Machinery expositions
Plant visits.

These sources speak for themselves.

How Discarded Equipment Is Disposed of

Discarded equipment is disposed of by being sold to other users, by being sold to dealers in used equipment, and by being scrapped. As the scale is descended from the high-production shop and the shop working against keen competition, it is found that there is a market for discarded equipment in the shops where not so much is required from a machine and where competitive conditions are not so severe. It is not good economics to throw into the scrap machines that possess a good part of their life and of course they are going to be sold and resold just as automobiles are.

Whether the machines are sold direct to the new users or to dealers in used machinery depends upon market conditions, and the effort that the seller is willing to make to find customers. Evidently there is an economic need for the dealer in used machinery, since he retains his place in the industry.

Among certain users of machine tools there is a policy not to allow discarded machines to stand around for long periods. If there is no market available within a reasonable length of time (about six months) after the machines are taken from the equipment, they are broken up for the scrap. One of the reasons advanced in favor of rapid disposition is that antiquated machines have a bad influence upon shop morale when they stand around. Another is that the floor space is too valuable to give over to them.

Faults of Machine Tools

In selecting equipment that will give better service and bigger profits, the user of machine tools must, of course, take into consideration what to him are the faults of the machines he is using. There are two things to be desired in this matter of faults: One is that the user would report all shortcomings to the builders and the other is that the builders would give such reports the consideration that they deserve.

Among the faults that have been charged up to machine tools by users who constitute on the whole a very desirable market, as to volume, are these:

Some parts made of wrong material
Improper lubrication
Improper tooling
Wrong application to work in hand
Overloaded
Too wide a range in speed and feed variations
Cost of repair parts too high
Repair parts frequently do not fit
Loose-pulley bearings poor
Bearings too small to take care of the added load due to dull cutters
Table bearings and knee slides of milling machines need greater attention
Locking devices do not lock
Heavier tables are needed on drilling machines, and more adequate arms needed to support them
Flywheels are needed to absorb shock
Flexible mounting of driving pulleys would be an improvement. Machines equipped with them would fit into line manufacture whether set parallel or at an angle to the line
Something should be done toward uniformity of the heights of tables
Further study of the causes of chatter is needed to improve design
The master tools of industry should be started in life with greater accuracy
Some machine tools are built too hurriedly, in order to offset a competitor's lead
Poor workmanship
Wrong selection of materials
Not enough oiling capacity
Not enough ball and roller bearings
Present-day multiple-spindle operations require too long a time in indexing
Slides are too short on some machines
Punch presses should be heavier
On some machines collets are too light
On some machines shear pins should be provided. On others the shear pin should be closer to the work to protect more of the mechanism
Standard machines are seldom capable of operating at speeds as high as desired
Punch presses could be equipped with friction wheels to drive against the inside of the rim, and with soft brass wire shear rings between screw and pitman, so that overloading will cause the friction wheel to slip, and double-heading or other interference will cause the wire safety ring to shear.

No attempt is made to justify or deny the faults enumerated. All of them have been named by earnest users of machine tools.

Drive

There is a great difference of opinion as to the best method of drive for modern machine tools in modern shops. Individual motor drive and group motor drive with belts from overhead works to the machines are receiving most attention. The method of transmitting all of the power from a single unit by means of lineshafts seems to be out of the running.

The proponents of the group drive advance as their principal argument the lowering of the power factor when many motors are running at less than full load. They point also to the greater investment in motors when individual motor drive is adopted.

Those who favor the individual drive are inclined to believe that the advantages of the absence of belts, with greater cleanliness and better light, and with accessibility for service by overhead cranes, more than offset any increased costs. They point out also, that, with group drive, when a transmission line or motor goes out, the entire group is out; that there is much waste when only a single machine or a few machines are run overtime; and that the advantage of the flexibility of the individual drive in positioning and moving machines is a sufficient claim in favor of that type of drive.

To the author it appears that each shop must work out the problem for itself, and he points out the situation as a suggestion to the machine-tool builder that the prospective buyer of his equipment may have very good reasons back of his desire for just the kind of drive that the builder is not furnishing, no matter which kind it be.

Favor is sometimes shown the single-pulley drive because machines so equipped are more readily sold as second hand. The fact that electric current differs in different localities is another point in favor of the single-pulley drive.

Single-Purpose vs. Standard Machines

To some extent the selection of single-purpose or standard machine tools is comparable to the selection of one or the other type of drive. Some manufacturers lean very heavily toward the special, single-purpose machine. It is probable that they do so because they find that it pays, even when no such machine is available on the market, but must be designed and built in their own factories. There are others who will almost go out of their way to stick to standard machines. In favor of the single-purpose machine is the fact that it can be shown to pay on work of great volume and of fixed design. On the other hand, the standard machine has greater resale value and does not limit changes in the design of product.

Machine-Tool Records

The importance of machine-tool records has been brought to the author's attention. If we agree that plants should be kept modernized, we must agree, he thinks, that the machine-tool record is indispensable, not alone for cost, depreciation, and inventory purposes, but for carrying a record of the costs of repairs and comparative data needed in dealing with the equipment problem.

In writing of his equipment policies for the *American Machinist*, the factory manager of a famous plant said,

> Our repair cost records serve as a guide as to the time when a machine should be placed in the obsolete class. They serve also as a guide in the matter of rebuilding, of which we do probably more than the average amount. We consider repair costs so important that we budget the payroll of the repair department monthly, projecting the budget three months ahead. The budget is based on productive labor according to our output schedule. When the cost of the repair payroll exceeds the budget allowance, one or both of two things must be wrong. Either our repair gang has not worked efficiently or we are repairing where we should be buying, or both. Since we are able to check our repair labor very closely, we are most likely to find that we are nursing along some machines that we should be better off without.

The Human Equation

One of the advantages of up-to-date machine equipment is the effect upon employees. It is human nature to want to live in a modern house, to own an automobile with the latest improvements, and to want to work with the latest equipment. The author was told recently in a big and comparatively new shop where there are none but individually motor-driven tools, that when the men were moved from an old shop, with older methods of drive, into the new one, some of them said that they grew six inches.

It is not uncommon for managers or equipment engineers to believe that there is a noticeable increase in production when new and modern equipment is used, due to its effect upon the morale of the operator and entirely aside from increase due to the greater productivity of the equipment.

It seems quite possible, as has been explained to the author, that there is a psychological effect upon men of the movement of materials, for example, on conveyors, and for that matter, on rapid-production machines, that induces an ambition to maintain the movement; or even to accelerate it.

Modern machinery has taken much of the onerous heavy labor from the backs and hands of the workmen. Power rapid-traverse mechanisms have eliminated the heavy and time-wasting cranking formerly necessary to elevate cross-rails and to traverse heads and tables. Improvements such as push-button control have reduced danger to both machinery and men and have saved much time formerly wasted. Proper and complete guards have greatly reduced the hazards of machine-shop work, have saved much suffering and much money. Convenient controls have added to the day's production and have made it possible for the operators of the heaviest machines to leave the shop after a day's work still comparatively fresh. These improvements, inherent in up-to-date equipment, have benefited machine-tool-building and machine-tool-using industries greatly because of the increased satisfaction of the shop personnel.

These facts are being recognized, and with that recognition there is a growing appreciation of the value of the opinions of the men in the shop concerning equipment. Usually expression of shop opinion is secured from the foremen. More and more wide-awake concerns are giving their foremen a voice in the selection of equipment. A large concern, to which the author has referred previously, has gone so far as to insist that all recommendations for equipment must originate with the foremen of the plant. To follow such a policy does not mean that the superintendent, or the manager, or the president, need sit by and wait until the foremen have discovered needed equipment. It does mean a tactful plan for getting the foreman to sell himself in regard to that equipment and finally to recommend and request it.

Where high-production programs are in operation there are two methods of introducing new machine tools into the production. One method is to put them into the line as soon as received and the other is to try them on a production basis in an experimental department. The choice of method depends upon the type of management and the type of operators. It is needless to say that the experimental method is necessary in some shops, and there is much in its favor even when not necessary, especially if the man who is to operate the machine is allowed to help put it through its experimental paces. Prejudices that exist in the shop can be overcome by proper management, which includes the introduction of new equipment in a way that allows for existing conditions.

Conclusion

In conclusion there are several interesting facts that seemed to have no place in the paper up to this point as it is subdivided.

In the matter of loading machine tools there are two policies followed: One is to load them well within their rated capacities; and the other is to give them all the load they will stand. Without going into great detail, the reasons for underloading are to secure long life with a minimum of maintenance and repair expense. The reason for crowding, or overloading, is to get out of the machines all the production they can deliver before they become obsolete. The overloading is done with full expectation of shorter life and higher repair costs.

An instance of the profit accruing because the overloading policy was followed came to the author's attention. The introduction of a single change in the method of making a part caused the replacement of 300 of one type of machine by 30 of another, for the same output. It is quite a task to dispose of 300 machines of one type in the second-hand market, and in the case cited the manufacturer's consolation was that while the machines were in use he had made them much more than pay for themselves by loading them to capacity.

Replacement of machines by groups is many times advisable, especially in piece-work departments, where a new or improved machine tool would give one operator an advantage over the others.

Machine-tool salesmen as a whole receive the praise of some buyers and the adverse criticism of others. What seems to be certain is that most users of machine tools, of the type that understands the equipment problem, want real engineering service in selling. Expressed very succinctly, what is wanted is a kind of salesmanship that will have as an objective, before everything else, the interests of the buyer.

The last point is that automatic operation and feeding are growing in favor. The magazine is preferred to the hand feed where applicable, and the hopper feed, where the parts can be shoveled in, is preferred to the magazine. The limits to the magazine and hopper feeds are recognized, of course. However, their use is increasing, and must be taken into consideration.

The Prerequisites of Successful Polishing

By BRADFORD H. DIVINE,[1] UTICA, N. Y.

The author discusses those conditions which must be obtained in the polishing department to procure the highest quality of work with the least cost of material and wages. The most important consideration in successful polishing is the glue used in bonding the abrasive to the wheel and its treatment. The next most important consideration is the selection of the abrasive. These are discussed in detail. Other important factors are: the design of the article to be polished, relation of operations preceding polishing, absence of vibration, housing of the polishing department, polishing machines, automatic polishing, and polishing tools.

THE TERM "polishing," as it is used in the metal-finishing industry, is a misnomer. Strictly speaking, the term should be applied only to those operations which produce luster. As a matter of fact, in the industry it is applied to three distinct processes—flexible grinding, polishing, and buffing. In this paper, however, the term will be used in its commonly accepted meaning.

Flexible-grinding processes are those employed for the reduction of metal where only bright, clean, or smooth surfaces are desired; or as the base for luster or for plating, painting, enameling, or other finishes. Polishing, to use the term correctly, is the process employed where luster only is desired, usually following flexible grinding. Buffing is also a process where luster only is desired, usually on plated surfaces or on non-ferrous metals. Both flexible grinding and polishing processes employ flexible wheels with abrasives glued to them, while buffing operations employ only buffing wheels impregnated with buffing compositions as the abrasives. In the final analysis all three processes are simply varying degrees of grinding.

Polishing is a very old art, dating back to the Stone Age; and, while it has become one of the largest and most important departments of metal manufacture, it has not been developed along engineering lines as have other departments. It has been, with some exceptions, a matter of rule-of-thumb, tradition, or just plain habit or ignorance.

The industry, in general, is in a state of chaos. Costs are altogether too high, mechanical operations are often performed in a crude and inefficient manner, and standardization is conspicuous by its absence. One of the most prominent men in the polishing industry in England, whose company has been in the business of manufacturing polishing equipment for more than one hundred and fifty years, wrote to the author a short time ago: "Polishing is one of the things which have developed from the experience of the workman rather than through scientific investigation." As a result, we have an industry in which engineers and executives have, until recently, manifested little interest.

Dr. Hutton, head of the British Non-Ferrous Metals Research Association, in discussing this question recently wrote as follows:

> For some reason or other, most manufacturers in the metal industry over here seem to be much more keen on devoting time and money to developing other sections of their manufacture, and the polishing room is left as the "Cinderella" of the works. Whereas, of course, it is one of the most expensive factors of production in many manufacturing plants, and would yield great economies if properly brought up to date.

Under present conditions when the executive or engineer seeks information on polishing, he usually runs into difficulties. If he tries to get information from the polishers, he is likely to encounter a smoke screen. He is brought to the realization that the polisher's job has been to polish, not to record statistics or set standards, and that polishing foremen are more interested in getting out production than in studying the science of polishing.

The experiences of two engineers, as recently stated to the author, is typical of what is found when information is sought on polishing problems. One, connected with a concern well known for its efficiency methods, was delegated to standardize the polishing department. After spending some time in the department, he was obliged to report that he was unable to find a point from which to start. The other, an engineer prominent in the brass trade, accepted a commission to provide an industry in France with standard processes for finishing a certain metal, thinking his experience in brass would provide the data. He soon found his mistake. He then searched the libraries of universities and engineering societies for textbooks on the subject. He found absolutely nothing.

There are no textbooks, no recorded information generally available, and no standard terminology in the industry. Even encyclopedias and dictionaries contain little information, and some of them do not even use the words, "polishing" and "buffing."

The subject, "The Prerequisites of Successful Polishing," comprehends the entire problem of the equipment, tools, materials, processes, and standardized control of the polishing department. The points to be considered in this paper are:

1 The design of the article to be polished
2 Relation of preceding processes to polishing
3 Absence of vibration
4 Housing the polishing department
5 Polishing machines
6 Automatic polishing
7 Polishing tools
8 Abrasives
9 Glue.

Design of the Article to Be Polished

Polishing begins in the drafting room. Wheels of large diameter are more economical to use than wheels of small diameter. The article to be polished should be designed, therefore, to eliminate all unnecessary projections, depressions, angles, recesses or reverse curves, which can be polished only with narrow or small wheels at excessive costs. Usually the cost of any extra metal involved can be more than offset by the saving in polishing.

Relation of Preceding Processes to Polishing

The polishing department receives the work in either rough or tooled condition. When castings are to be polished without previous operations, they should be as free as possible from excessive sprues, ragged edges, lumps, or other similar surface defects. With forgings, as much scale as possible should be removed by pickling or other methods. In drawn or stamped work deep drawing marks or scratches caused by imperfect dies should be eliminated by correcting the dies. Work which is tooled, or which is ground on solid wheels, should be so processed that the surfaces will not be too rough. Deep tool or grinding marks necessitate the removal of too much metal to reduce the entire surface to the level of the bottom of such marks.

Work should be delivered to the polishing department in such condition that it will not be necessary for that department to correct the errors of other departments. The cost of correction in the polishing department usually exceeds the cost of correction in the department where the incorrect condition originates. There is often continual strife between the polishing and other departments on this point, whereas care in planning would prevent such conditions. This is one of the underlying causes of the high cost of polishing.

An example of what can be done to help polishing by a study of previous processes is the experience of an ax factory. The forged ax when it left the dies was true to contour, but with an extra thickness of metal to allow for grinding off the scale. The solid-grinding operation to remove the scale destroyed the contour and left the surface in scallops or waves. It required at least three operations, which should not have been necessary, to restore the contour and prepare the surface to take a polished finish. The installation of a cheap and simple process for removing the

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scale while the metal was red hot eliminated the solid grinding and several polishing operations, and greatly reduced the cost of finishing.

ABSENCE OF VIBRATION

The absence of vibration is necessary for successful polishing. A polishing wheel, like any high-speed unit, is susceptible to vibration. A vibrating wheel makes scratches which cost time and money to remove. A polishing wheel works at best efficiency only when the entire face of the wheel comes in contact with the articles being polished at every revolution of the wheel.

Vibration comes from several sources—the building, the machine, or the polishing wheel. The building may be of light construction, or the floors may be too light to provide a sufficiently rigid foundation for the machine. The machine may be too light, or not well designed. It may not be properly secured to the floor, or may not have the necessary rigidity in the column, the shaft, or the bearings. The polishing wheel may be of such a type, or may be so designed, that it is difficult to balance. Then too, the wheel may be so headed that high spots or hard spots are developed, which throw the wheel out of balance.

Fatigue of the operator is another reason for eliminating vibration. The author was approached by a polisher in a local plant in which had been installed wheels of a type which ran much more smoothly than those previously used. The polisher said that the vibration from the old wheels caused such lameness in his arms that he was used up by two o'clock in the afternoon. At the end of the day, he was completely exhausted. The new wheels, having no vibration, enabled him to work with less fatigue, and he could enjoy his evenings with his family. Moreover, he was making more money on his piecework rate.

While the vibration in this instance arose from the wheel, it may be assumed that the effect would have been the same had it been due to other causes.

HOUSING THE DEPARTMENT

The building housing the polishing department should be of solid construction. Floors should be heavy so that polishing machines may be firmly fastened to them. Rooms should be well lighted so that the operators can critically inspect their work. The department should be clean, both for sanitary and mechanical reasons.

There is no reason why the polishing department should be treated as "the Cinderella of the works," as Dr. Hutton says. Conditions in this respect are, however, improving; but many polishing departments are still to be found in basements or other unsuitable places. The idea seems to be that polishing is such a dirty business that the location of the department makes little difference.

Good dust-collecting systems should be installed in order that the dust from the wheels may be quickly removed. Abrasives will fly from the wheels; and if the grains from the coarse wheels come in contact with work undergoing finer operations, deep scratches will be caused which oftentimes the operator cannot account for. It costs money to take these scratches out.

POLISHING MACHINES

Rigidity and durability are the factors of greatest importance in polishing machines. The items which enter into these factors are the size of the machine, its weight, the floor area of the base, the design and construction, the size, the location and type of bearings, and material in the shaft and its diameter.

Rigidity, preventing vibration, has a direct bearing on the efficiency of the machine and the cost of the polishing done on it. This is not always evident until it is analyzed, but the following experience shows it to be true.

A concern establishing a polishing department bought the best electric belt-driven machines it could find on the market. After using them a while, trouble developed, and it decided to build some machines of the same general type as those purchased. After the machines were constructed, comparative tests, made by the same operators using the same wheels on the same class of work, showed that the new machines enabled an operator to produce from 12 to 20 per cent more work due to the absence of vibration.

Another factor that enters into the question of rigidity and durability in machines is that, with improved glue-handling methods, peripheral speeds of from 7000 to 10,000 ft. per min. can be used, requiring a better class of machines than those used a few years ago when peripheral speeds rarely exceeded 5000 ft. per min.

Another question of considerable importance in polishing machines is that of variable speeds. This is particularly true in buffing machines. All buffing wheels, and a great many polishing wheels, wear down in diameter. They operate, therefore, at a constantly reduced efficiency, due to decreased surface speeds. The most common form of direct-connected, electric-driven machine is that using alternating current which, of course, operates at a fixed speed. Direct current, permitting the use of variable-speed motors, is found in only a few localities. To transform alternating current to direct current has been found to be too expensive to be generally satisfactory.

The best answer to this variable-speed question seems to be the machine with the electric motor built into, or attached to, the column of the machine and belted to the wheel shaft. This type of machine is rapidly replacing all others were variable speeds are necessary.

Another form of variable-speed machine recently introduced uses bevel gears, in which, by changing the gear ratio, variable speeds are secured.

AUTOMATIC POLISHING

Automatic polishing is rapidly taking its place in the industry for processing large productions of flat pieces, or pieces having a portion of their surfaces flat, such, for instance, as the flat parts of pliers; or such articles as plane blades, flat irons, monkey and pipe wrenches, sheet metals, strip steel, flat bars, knife blades, and any work which is flat or practically so.

While, at present, interest in the automatic polishing of flat work predominates, round bars, tubes, and contoured pieces are also being successfully produced on automatic machines. The variety of work capable of accomplishment by automatic processes is rapidly increasing.

Automatic polishing is not, however, as simple as many people have thought it to be. Many conditions arise not present in hand work, for the machine is without the human "feel." The work and the wheels are in fixed positions in relation to each other, and the machine cannot correct imperfections in the work as the hand operator can. It is necessary that the work be brought to automatic machines in better condition for polishing than for hand work. Flat work must be absolutely flat, and it is often necessary to straighten or flatten work before polishing.

The difficulties encountered in automatic polishing are not so much in the machines as in the lack of ability of the operators in charge of them to tool them and operate them properly. The wheels must be manufactured especially for the work. Wheels of different character than those used for hand work usually are necessary. Absolute trueness and perfect balance are essential. The wheel must contain within itself the characteristics and qualities which will take the place of the human "feel" in hand work.

The heading of the wheels is a problem requiring much more expertness than in hand work. The head must be as strong as possible to avoid too frequent wheel changes, causing stoppage of production. Provision must be made for keeping the wheels cool, for the almost continuous application of work to the wheel generates much more heat than in hand work.

That automatic polishing reduces costs and speeds up production is shown by the following examples. On one automatic machine, hot-air registers 40 in. square are being solid-ground, flexibly ground, and polished ready for enamel (a ten-wheel operation), in 5 min. and 40 sec. each. On another machine 2400 flat-iron bottoms per hour are finished—one every $4^2/_3$ seconds. In another case 3500 small flat pieces per hour are turned out by one man operating three machines. In the steel trade a ton of cold-rolled sheets 36 × 60 in. has been polished, one side at a time, in 38 minutes.

An interesting effect of automatic machines on the polishing problem was illustrated by an experience in one factory where operators were turning out 175 pieces per hour by hand, claiming

that was their limit. An automatic machine was installed with a guaranteed production of 500 pieces per hour. It did as guaranteed, and then the polishers said they could do as much as the automatic machine did. It is not likely that operators on other work in that plant continued to retard production.

POLISHING TOOLS

A tool usually has some particular characteristic and quality which enables it to perform an operation better than some other tool. When a tool wears out it must be possible to replace it with an identical one. Like all other tools, there is one best polishing wheel for every operation.

Polishing wheels, unfortunately, have been considered and purchased altogether too much from the standpoint of merchandise; and the fact that they are tools of very considerable importance has been somewhat lost sight of. In the manufacture of polishing wheels, too much consideration has been paid to something to sell at a competitive price rather than to the development of the tool itself in the proper relationship to the work it is to do. The general theory has been that anything round, which will yield, and provide a cushion on the face, and to which abrasives can be glued, is a polishing wheel.

The function of the wheel is to act as an agent for carrying the abrasive, and to provide the necessary cushion so that the wheel may properly execute its cutting function. The wheel should be perfectly round and true in order that the entire surface of the face of the wheel may be cutting at every revolution. A wheel which has high spots on it, or is uneven on the face, will present only a part of the abrasive head to do the cutting, with the result that the operator has to employ more time to reduce a given amount of metal—and time as represented by operators' wages is the most costly item in the whole operation of polishing.

Polishing wheels may be separated into three general classes varying according to their characteristics and adaptation to the different flexible-grinding or polishing operations, grading from the coarsest grinding to the finest finishing operations. One class is that in which the wheels are made in disk form, the materials commonly employed being disks of leather glued together; disks of canvas sewed or cemented together or held in position by metal side plates; disks of woven felt sewed or glued together; disks of sewed buffing-wheel sections, each section individually sewed, and then the sections either sewed or glued into the unit of the wheel, or held together by side plates.

Another class of wheels is that which may be designated as the "crosswise" type. This class of wheel has steel or wood centers around which are placed blocks of leather, canvas, felt, or other materials, the blocks lying radially to the axis of the wheel and crosswise of the face. This position of the material is diametrically opposite to that in the disk type of wheel.

The third class is the wheel with a solid one-piece face. The leather-covered wood wheel is the commonest type of this construction, although leather strap faces are used on solid paper wheels or as a covering for the crosswise type of wheels. Solid felt and solid walrus wheels come in this class of solid-faced wheels.

In general, the disk type of wheels are used for the roughest, coarsest grinding operations. The crosswise types of wheels are more commonly used for practically all operations from the coarsest grinding to the finest finishing, depending upon what the degree of coarseness and what the degree of fineness is. The strap-faced wheels are, or should be, used almost entirely for the finishing operations which produce the lustrous or mirror finishes, or on flat work.

In considering the type of wheel to be used comes the question of the shape of the piece to be polished. A piece which is curved will require the softer types of wheels either of the disk form or the crosswise type. If the piece is flat, all of the operations may be performed to better advantage on the crosswise or strap-faced wheels. There are, however, very many degrees of gradation in these questions, upon which the selection of the proper type of wheel is based. It is impossible to attempt to cover the many phases of the question in this paper.

The selection of the proper character of wheel also requires consideration of the cost of using the wheel. It is characteristic of all wheels of the disk form that the face wears out of shape, and also that the wheel wears down in diameter. Where a flat piece of work is operated upon with a disk form of wheel, it frequently is necessary to true the face of the wheel, reducing its diameter, in an effort to keep the face flat. With this reduction in diameter and lessened surface speed, the element of time is increased.

In the wheels of the crosswise type there is less tendency for the wheel to wear down. The fact that the pieces of polishing material are across the face of the wheel, and are not disks, prevents the wheel from wearing in ridges. Such wheels often remain practically full size and in a condition almost as good as new for many years, whereas the wheels of the disk construction are constantly worn out and replaced.

With the strap-faced form of wheel, while the body of the wheel may remain practically full diameter, it is necessary to replace the lather strap frequently.

Wood wheels with the leather strap faces are made in layers to prevent warping and splitting. Such wheels, unless the wood is thoroughly seasoned and set, commonly expand and contract unevenly in the different layers, causing ridges on the face. It is difficult to keep any wood-block wheel round and true.

The amount of cushion in a polishing wheel is a very important factor in the polishing operation. The amount or degree of cushion in a wheel is secured either by the use of different materials or by the manner in which the materials are arranged in the wheel. The object of the cushion is to permit the face of the wheel to flatten and cover as much area on the work as possible, to grind away as much metal as possible at each stroke, and to provide a smooth cut. The degree of cushion also has a decided effect in securing the finished surface desired.

For the classes of work for which the disk wheels are more commonly used, such as the rough grinding of agricultural tools, the exact degree of cushion is not so essential; but for hardware or other work requiring well-finished surfaces, the proper degree of cushion is highly essential. On some classes of work density is such an important factor that a difference of one degree will render a wheel too hard or too soft for a particular operation.

In wheels of the disk or the solid-faced types, the range of densities is quite limited, usually to three degrees: hard, medium, and soft. In the crosswise types the range of densities is much greater. In some types it is possible to secure as many as eight degrees. In this type also it is possible to regulate the density to a much more accurate degree than in other types, and this type also permits the exact duplication of density when replacing or duplicating wheels.

A factor in wheel economy is the diameter and width of face of wheels. It is advisable to use a wheel as large in diameter as the article being polished will permit, in order to secure the maximum contact of the wheel with the work necessary to remove the greatest amount of metal at each stroke.

Large wheels have less tendency to heat than small wheels. Heat is generated only at the point of contact between the wheel and the work. On the large wheels the heated area has a greater opportunity to cool before returning to contact with the work than would be the case with smaller wheels.

It is also advisable, where possible, to use a face much wider than the piece being polished in order that the piece may be moved about on the face of the wheel and not wear the head in one spot.

The use of wheels of large diameters and wide faces reduces the investment in wheels because of the smaller number required. It reduces the cost of caring for wheels, and of reheading them. It also reduces the time lost by operators in changing wheels.

If time permitted, it would be interesting to follow out the details of the wheel question—the treatment of new wheels, the application of the preliminary sizing coats, the number of them, the manner in which they should be applied; the application of protective coats of heavy glue placed upon the sizing coat and preparatory to receiving the working head; the different kinds of heads, the methods of applying them to the wheel; the uses of the rolled head and the paste head; the number of coats of abrasives; the dressing off of the old head after it ceases to cut; the manner of handling the wheels in wheel-drying rooms; the characters of the various processes for coarse grinding, fine grinding, glazing, coloring, greasing out, and oiling and other

similar questions. Any one of these phases of the question would provide enough material for an entire paper of itself.

Abrasives

The abrasive grain, which does the actual cutting, is one of the two most important prerequisites of polishing. Glue is the most important, and the grain is secondary only because the grain cannot be given a chance to do its best work unless firmly bonded to the wheels by the glue.

There are two kinds of abrasive grains in common use—emery, which is a natural product, and grains which are manufactured from bauxite.

Emery is impure or low-grade corundum containing magnetite or hematite. The corundum is that portion of emery which does the cutting. The other materials are inseparable from the corundum particles; they have no function in the cutting operation, and tend to modify the cut of the emery. This modification of the cut is considered by some to be advantageous in the finer operations employed for the actual production of luster. For flexible-grinding operations, the manufactured abrasives are far superior to emery.

Examined under the glass, the manufactured grain appears very much like sharp pebbles, uniform in size, and containing no foreign matter. It differs from emery in being more uniform in hardness or temper. Each grain is so constructed that when properly bonded to the wheel it will fracture away piece by piece, each fracture presenting a fresh cutting edge until the grain is consumed. Wheels headed with manufactured abrasives have less tendency to glaze than those headed with emery.

Care should be taken in selecting manufactured abrasives to see that they are free from slivers or elongated grains which would scratch the work.

Manufactured abrasives are treated to provide capillarity in order that the glue may grasp them firmly. In the storage of them it is important that they be kept free from moisture which might tend to deteriorate this capillarity and weaken the glue bond.

A great many concerns have been unable to secure as satisfactory results with manufactured abrasives as with the natural emery. The difficulty was not due to the grain itself, but entirely to the use of inferior glue, or to improper glue-handling equipment and methods. The manufactured grains are harder than emery, and therefore require a stronger bond.

Care must be used to see that the proper sizes of grains are used in the proper sequence from the coarser to the finer operations. For instance, in certain cases where a No. 46 grain may be followed by a No. 80 grain, the gap between the grains may be too wide, and a much faster reduction of metal would be secured by following the No. 46 by a No. 60 or No. 70. If the gaps between the grain sizes are too great, the effort of the operator to reduce the metal by increased pressure against the wheel to make it cut, often burns the ridges, causing discoloration. Then, too, the coarse ridges have a destructive effect upon the wheel heads of the finer abrasives following.

One of the evidences of the wastage caused by the improper bonding of the grains to the wheels is the fact that a business has been made of reclaiming abrasives which have been torn bodily from the wheels, resizing and selling them. This on the face of it may seem like a good thing, but a little thought will show that, had the grains been properly bonded to the wheels and consumed by fracturing away in the polishing operation, as previously described, there would be no necessity of a reclaiming process and no grains to reclaim. Where the grains are torn from the wheels through improper bonding, and not reclaimed, they are, of course, wasted.

Another important feature in handling grains is the proper consistency of the glue for the different sizes of grains. If the glue is too thin for coarse grains, it will not provide the proper body to hold the grains. If the glue is too thick for the finer grains, the cut of the grains will be modified, a glazed condition of the wheel face will result, and wastage occurs. As in other conditions when the wheel ceases to cut freely, the inclination of the operator to force the wheel by excess pressure is likely to burn the metal, to require extra time for an operation, and to soften the glue on the face of the wheel (which in itself decreases the cutting ability of the abrasives), and the whole process becomes destructive and expensive. Researches are now being made to determine the correct consistency of glue for the different sizes of abrasives.

Glue

Glue is the most important prerequisite of polishing. When it is realized that the abrasives glued to polishing wheels have to perform practically the same operation of grinding away or tearing down metals as solid vitrified wheels do, it will be evident that glue as the bond between the wheels and the abrasives is the most important factor in polishing. The efficiency of the combination of the wheel and abrasive as the cutting tool depends almost entirely upon the strength of the glue bond. The ability to secure the desired finished surface, and the cost of securing that surface, depend upon the strength of the glue bond. In fact, glue is the keystone of successful polishing.

The reduction of the processes of glue handling to a definite formula has been one of the most important steps toward the standardization of the polishing industry. However, to utilize such a formula to the best efficiency, the glue, handling equipment, and all factors pertaining to it must likewise be standardized.

In spite of the fact that the use of glue in the mechanical arts is traceable over 3300 years, the use of glue seems to be little understood. One glue manufacturer has stated that with the consumption of 80 million pounds of glue annually, he doubts if 20 per cent of those using it have the vaguest conception of what glue is or how it should be applied. The author would go farther and say that not three men out of a hundred in the polishing industry have a proper conception of what glue is or how it should be applied. Also, the influence of glue and glue processes upon polishing operations and costs is little recognized.

Every pound of glue wasted through inefficient methods carries with it a considerable wastage of abrasive grain. A recent experience showed that by simply changing the process of using glue, the same amount of work was produced with one-half the quantity of glue and abrasives. Going farther, the right kind of glue reduced the quantity again so that the same amount of work was produced with from 20 to 25 per cent of the glue and abrasives originally required. In other words, by using standard processes with the proper glue, four and five times as much work was produced from each wheel head.

Glue is commonly purchased on a price basis rather than on a quality or performance basis. If price alone is to be considered, the basis of comparison should be the cost per quart of liquid glue ready for use. Glues of the better qualities will take more water to the pound of dry glue than glues of inferior qualities, resulting in a lower cost per quart of melted glue. The price of glue, generally speaking, is indicative of its quality.

The higher-grade glue shave greater strength, and are better adapted to polishing than glues of lower grades. However, the strength of glues of higher quality can only be brought out by proper handling methods. Ordinary processes of glue handling often reduce the strength of high-quality glue to that of inferior glue. The author has actually seen 30-cent glue so reduced in value by the handling processes that it gave no better results than a 10-cent glue.

The glue which gives the most satisfactory results for polishing is the best-quality, first-run, straight hide glue. The characteristics necessary are jelly strength, toughness, viscosity, and—what is more important than anything else—flexibility. Many glues set hard and brittle, and are broken up and torn out by the bending action of the face of the wheel.

The first step in organizing a glue department and standardizing glue processes is the arrangement and equipment of the glue room, which should be entirely separate from the polishing department. Glue is a rather delicate thing to handle. It is easily affected by either high or low temperatures. The glue room should, therefore, be arranged so as to be free from drafts which would chill the glue. Windows when open should be equipped with deflectors. Doors should be on double-swing hinges to remain closed constantly.

The glue apparatus, and in fact the whole glue room, should be

kept as clean as a dairy. Glue brushes, when not in use, should be kept in a weak solution of carbolic acid in order to destroy the bacteria which may accumulate in them.

The glue heater should be of a type which will furnish a constant supply of fresh glue in its strongest condition. Glue should be mixed and used in small batches so that it may be consumed in four hours from the time it is melted. Otherwise, it deteriorates rapidly. The individual glue pot should be of a size, therefore, to contain only a four-hour supply of glue.

The multiple-pot system is preferable to the large single pot. The size and number of pots should be such as to provide for the different consistencies of glue required for the different-size grains, and also to allow extra pots for hot water and for sizing. Aluminum is the best material for the glue pots on account of its property of holding heat, and the ease with which the pots may be cleaned.

The glue heater should be equipped with a thermostat to maintain the glue at a uniform and correct temperature. Thermometers should be provided to check up the temperatures. Psychrometers should be provided in order to determine, when wheel heads do not last, whether the trouble is due to softening the wheel head by humidity or to some other cause.

Ovens should be provided to heat the wheels to 120 degrees. The abrasive troughs should have heaters to heat the grain to the same temperature as the wheels to prevent chilling the glue.

In addition to the glue-handling equipment, the glue room should be equipped with an accurate device for balancing the wheels each time after they are headed. The room should also be equipped with tools for removing the residue of old wheel heads. Water should not be used for this purpose when it can be avoided.

The wheel room should be separate from the polishing department. The partitions or walls should be arranged with openings both at top and bottom to permit a rapid circulation of air to carry away the moisture evaporated from the glue while it is setting. The temperature of the wheel room should be that of the working departments. Artificial heat should not be used, nor should the wheels be chilled. Both of these practices have a very detrimental effect upon the strength of the glue bond. Nature will take its own time in setting the glue, and it must not be interfered with.

There are two elements in glue handling which must be recognized and controlled. One is heat, the other is bacteria.

Heat makes glue, and heat destroys glue. The maximum strength of the glue bond, which enables it to resist the frictional heat generated in polishing, is secured only by a proper control of heat in the preparation of the glue.

Glue loses five per cent of its strength for every hour of heating. Laboratory tests have shown a loss of 67 per cent of strength after 12 hours under heat. Tests of a high-grade glue, made by the United States Forestry Bureau, showed a loss of one-half the glue strength in seven hours at a temperature of 176 deg. fahr. Glue is strongest at a temperature of 135 deg. fahr.

In order to secure certain definite results from the preparation of glue, certain definite procedures must be followed. Glue is somewhat like a chemical in that a slight change in the materials or in the formula used will make a considerable difference in the results obtained.

The conversion of dry glue into liquid glue of the strongest character is made by adding certain definite proportions (by weight) of either pure or distilled water to the glue, soaking it a definite time, and melting it by raising the temperature to about 135 or 140 deg. fahr. Different makes and qualities of glue require different proportions of water.

Ground glue should be soaked in cold water at least three hours; flake glue, eight hours; and cake glue, twelve hours. After the glue is soaked it does no harm if it stands twenty-four or even forty-eight hours, provided the temperature of the room is not over 70 deg. fahr. The glue when placed in the heater should be melted, not cooked or boiled.

To secure the different consistencies of glue required for the different sizes of abrasive grains, hot water should be added to the liquid glue. The proper consistency, once determined, should be recorded by instruments and standardized.

In applying glue to the wheel, no draft of air should come in contact with the glue brush, for instant chilling and serious weakening of the glue will result. The wheels and abrasives, having been heated to at least 120 deg. fahr., will then allow the whole mass of abrasives, glue, and the wheel to cool gradually without detriment to the glue strength.

Glue hardens in the process of setting much as concrete does. Setting begins with the cooling, but continues long after the cooling has reached its stopping point. A wheel head may be cold in an hour or so, appearing to be ready to use. As a matter of fact, a minimum of 48 hours is required to complete the natural process of setting glue to its maximum strength. The process of setting is, of course, the evaporation of moisture from the glue.

It is altogether too evident that very few people appreciate just what is taking place in the process of preparing and applying glue to polishing wheels. The idea seems to be to spread on the glue, apply the abrasive, and, as soon as the wheel is cool, start cutting metal with it. The usual result is extravagance, inefficiency, and waste.

The author has seen wheels headed up with a paste head $1/4$ in. thick, and within fifteen minutes used for grinding away metal. This was exhibited by a man who had been a polisher for 45 years, and who took pride in his so-called expertness in handling wheels.

A fact not apparently well known is that glue handling is a fight with bacteria, and again the question of heat comes in. Glue chemists tell us that the bacteria increase rapidly, consuming the strength of the glue, at temperatures higher than 140 deg. fahr. This is recognized in the manufacture of glue, which is cooked at temperatures of about 140 deg. fahr., and then the temperature is reduced as quickly as possible in the process of solidifying the glue to the point at which the bacteria become virtually inactive.

This is the reason why everything in and about a glue room should be kept as clean as in a dairy. The bacteria in glue which is left over night will contaminate fresh glue the next morning and decrease its strength probably 50 per cent. Bacterial action is one of the reasons why glue loses its strength either under prolonged heat or at temperatures above 140 deg. fahr.

One of the abuses in the use of glue has been the use of formulas for improving the glue, such formulas containing alcohol, dry lead carbonate or white lead, precipitate of chalk, and glycerine. Such formulas are entirely worthless. Another idea in common use in certain parts of the country is that the addition of a certain "gum" to glue will increase the strength of the glue bond. Analysis showed that the "gum" was nothing but wheat starch containing coloring matter to disguise it. Glue chemists tell us that there is nothing that will increase the strength of glue except Russian isinglass, the strongest adhesive known. Its cost is so high, however, that its use in the polishing trades is prohibited.

In addition to the points considered in this paper, there are two other prerequisites of successful polishing. One is the correct methods of processing the various polishing operations; the other, the supervision and standardization of the polishing department. However, to discuss the many points involved in the numerous and varied kinds of operations, and the use of those prerequisites already discussed in the execution of them, is not possible in the time allowed for this paper.

As to the supervision and standardization of the polishing department, the author's observation of the industry, both in this country and abroad, has convinced him that it is to the advantage of executives and engineers that they analyze their polishing problems; that they do not try to correct conditions by remedying the weak spots, but by making a complete and fundamental analysis as a basis for a systematic control and standardization of polishing departments.

Correction

IN Fig. 1 on page 719 of the July issue the caption should read, The Ford Stout Tri-Meter All-Metal Plane.

On page 781 of the same issue appears a discussion of Professor Everett's paper on A Temperature-Entropy Diagram for Air and the Diatomic Gases O_2, N_2, and CO by Prof. R. C. H. Heck. This discussion should have been credited to Prof. J. C. Smallwood of Johns Hopkins University.

Work-Hardening Properties of Metals

Their Relation to Metal-Cutting Operations and Cutting Temperatures

By EDWARD G. HERBERT,[1] MANCHESTER, ENGLAND

It is the object of the present work to correlate with the operation of cutting tools certain well-established and generally recognized facts, the chief among them being: (1) that metals are hardened by any process which deforms them so as to cause a permanent change of shape while they are at low or moderate temperatures, a process referred to as "cold work;" (2) that metals are deformed and are therefore hardened by cutting tools; (3) that heat is generated by deformation of metals and in a preëminent degree by metal-cutting operations; and (4) that the degree of hardness induced by working metals, with cutting tools, or otherwise, is greatly influenced by the temperature at which the deformation takes place. An attempt is made to show the bearing of these facts on the resistance offered by metals to the cutting tool, and on the rate of wear of the cutting tool. The relation between the temperature generated in cutting and the heat-resisting properties or "hot hardness" of the cutting tool, is touched upon. The limiting factor in the rapid removal of metal is ultimately the temperature generated in cutting in relation to the capacity of the cutting tool to withstand high temperatures. The present work deals with the heat-producing properties of the work rather than with the heat-resisting properties of the tool.

SECTION 1

The Hardness Induced by Cutting Tools

To investigate the hardness induced by the tool in the process of cutting metal, a bar of the metal under investigation was chucked in the lathe and a cut 1/4 in. deep was taken with a straight-edged side tool, the feed being 1/27 in. and the speed 65 ft. per min. The lathe was quickly stopped while the cut was in progress and the tool withdrawn, leaving a chip attached to the bar. A section was cut parallel to the axis of the bar through the chip and the adjacent metal mounted in fusible metal, polished, etched, and tested for hardness at a number of points around the zone of separation, by the time test, with the Herbert pendulum hardness tester. Conversion of the time hardness numbers, has been made into approximate Brinell numbers (in brackets) by the following formulas.

For brass $B = 0.29T^2$
For soft steels $B = 0.36T^2$
For steels harder than 280 Brinell $B = 10T$
or $B = 13.5dT$

where B is the Brinell hardness number, T the time hardness number using the 4-kg. pendulum and 1-mm. steel ball, and dT the time hardness number with 4-kg. pendulum and 1-mm. diamond. The diamond, owing to its greater hardness and rigidity, gives lower readings than the steel ball, hence the different conversion factors.

The metals selected for experiment were

A a mild steel of 35 tons per sq. in. tensile strength; time hardness 21.4 (163*B*)
B stainless iron (0.1C, 13.5Cr); time hardness 19.7 (140*B*)
C stainless steel (0.1C, 17.2Cr, 7.9Ni); time hardness 19.9 (142*B*)
D stainless steel (0.26C, 13.2Cr); time hardness 27.2 (265*B*)
E stainless steel (0.11C, 15.7Cr, 10.5Ni); time hardness 18.0 (116*B*)
F rod brass; time hardness 19.2 (106*B*)
G cast iron; time hardness 29.3.

Photomicrographs of the sections are given in Figs. 1 to 6, with charts giving the pendulum time hardness of each spot tested. The brass chips in Fig. 6 appear separate, but were actually attached at one end to the bar. It was not possible to obtain an attached chip of cast iron, but a sectioned chip was tested for hardness, the microstructure of chip and bar being shown in Figs. 7 and 8.

From these figures it appears:

a That in the brittle metal, cast iron, the tool caused no distortion of the metal and no work hardening.

b That in brass there was a slight distortion and a small amount of work hardening, as shown in Fig. 9.

c That in the steels the distortion of the structure was severe, and the hardening of the metal in all cases considerable, but very different in degree. Attention is drawn to the hardness of the metal immediately ahead of the tool where separation of the chip was about to take place. In every case except that of cast iron, the tool was actually cutting metal whose hardness was very different from that of the original bar. This is shown in Table 1 in which

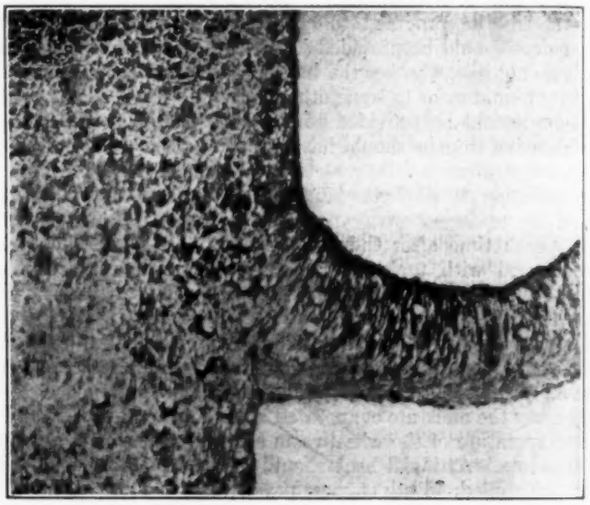

Fig. 1 Chip in Mild Steel A (×10)

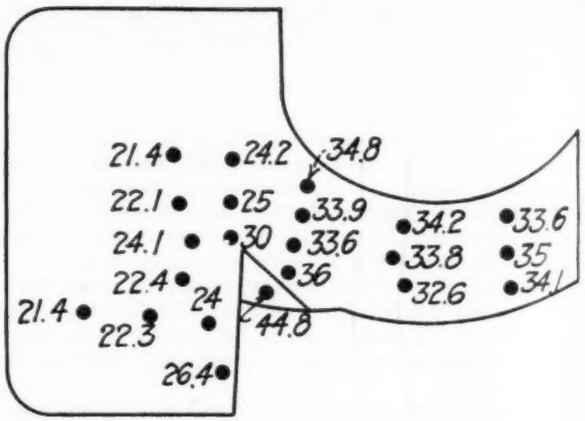

Fig. 1*a* Hardness Induced by Tool in Mild Steel A

TABLE 1 METALS ARRANGED IN ORDER OF ORIGINAL TIME HARDNESS

Specimen	Original hardness	Hardness in path of the tool	Time-hardness increase, per cent
Stainless steel E.....	18.0 (116*B*)	37.8 (378*B*)	110
Brass F.....	19.2 (106*B*)	24.1 (169*B*)	12.5
Stainless iron B.....	19.7 (140*B*)	31.45 (315*B*)	60
Stainless steel C.....	19.9 (142*B*)	43 (430*B*)	115
Mild steel A.....	21.4 (163*B*)	30 (300*B*)	40
Stainless steel D.....	27.2 (265*B*)	36 (360*B*)	32
Cast iron G.....	29.3	29.3	0

[1] Edward G. Herbert, Ltd.

Contributed by the Machine Shop Practice Division and the Research Sub-Committee on Cutting and Forming of Metals and presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers. Abridged.

the metals are placed in the order of their original time hardness. The hardness in the path of the tool and the percentage increase of time hardness at this point are given.

Five of the specimens were originally quite soft, and the specimen which had the lowest original hardness, stainless steel E (*T*18, 116*B*), was hardened by the tool to *T*37.8 (378*B*), being exceeded in this respect only by stainless steel C, whose hardness was increased by the tool from *T*19.9 to *T*43 (430*B*). The steel which had the highest original hardness, stainless steel D, was only slightly hardened from 27.2 to 36. The mild steel A was originally harder than stainless iron B, but under the action of the tool the order of hardness was reversed, while the hardest of all the specimens, cast iron G, was not hardened by the tool.

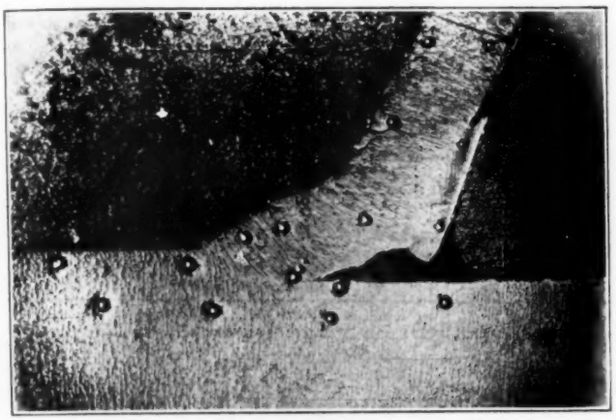

FIG. 2 CHIP IN STAINLESS IRON B (×10)

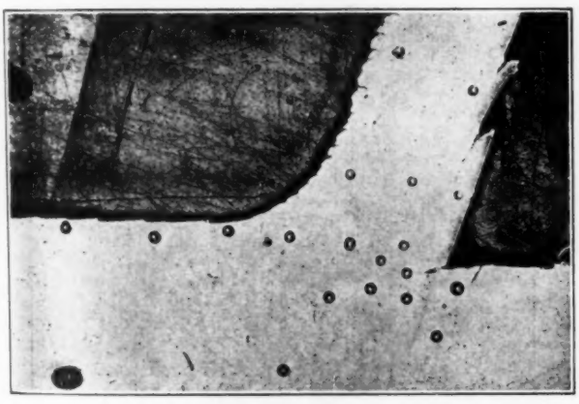

FIG. 4 CHIP IN STAINLESS STEEL D (×10)

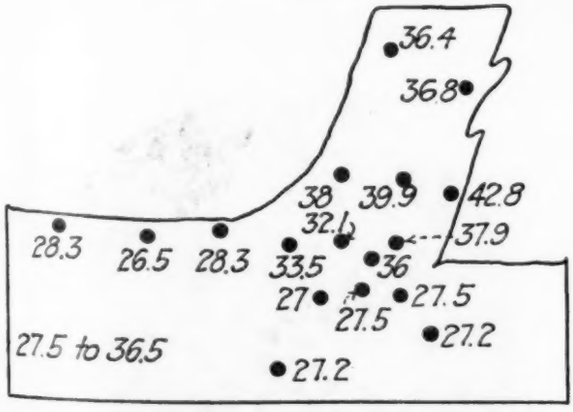

FIG. 4*a* HARDNESS INDUCED BY TOOL IN STAINLESS STEEL D

It is seen in Figs. 1*a* to 6*a* that there is in front of the tool a hardness gradient rising from the undistorted body of the bar toward the point of separation of the chip, and that this gradient is continued past the point of separation into the chip, where the greatest hardness is generally found. Cutting takes place at a point on this gradient which is always higher than the original hardness of the metal, but the hardness where cutting takes place differs from the original hardness according to the (*a*) ductility or brittleness, and (*b*) capacity for work hardening of the metal.

In estimating the resistance which a given metal will offer to a cutting tool, the predominating factor must be the hardness of the metal which the tool is actually cutting, since this determines the force which the tool must exert in order to crush and rupture the metal. In estimating the machinability of a ductile metal by its destructive action on the tool, three factors come into play, the

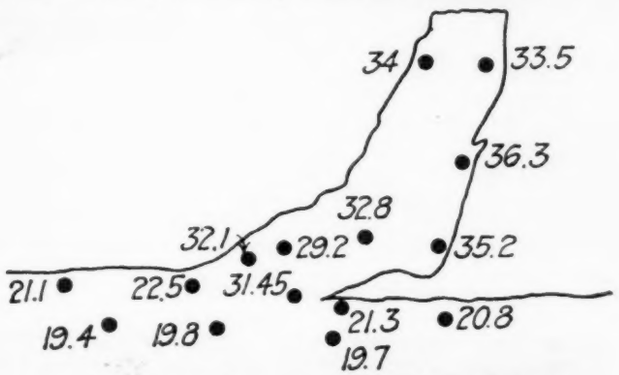

FIG. 2*a* HARDNESS INDUCED BY TOOL IN STAINLESS IRON B

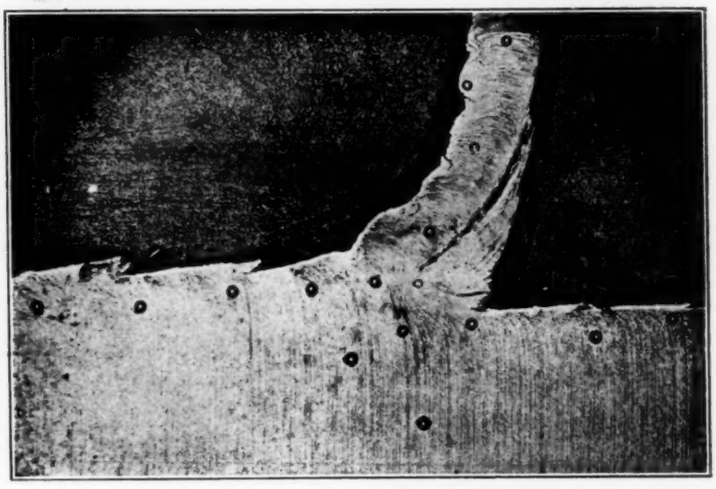

FIG. 3 CHIP IN STAINLESS STEEL C (×10)

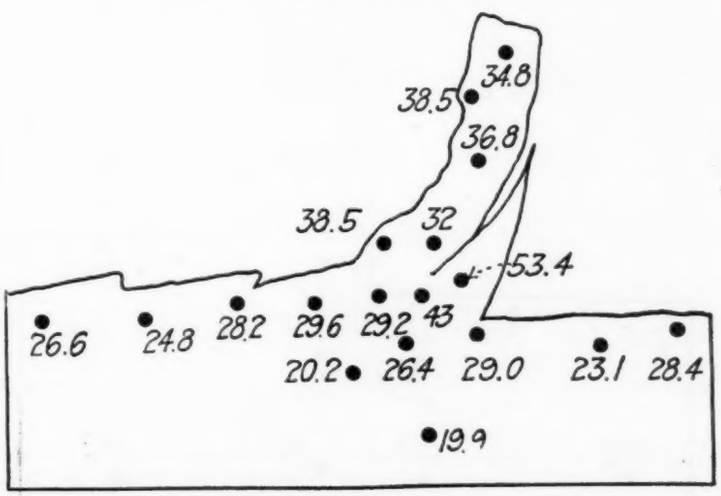

FIG. 3*a* HARDNESS INDUCED IN STAINLESS STEEL C

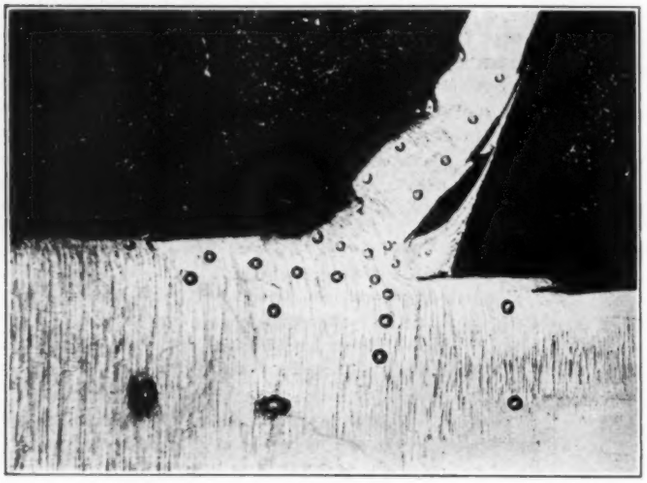

FIG. 5 CHIP IN STAINLESS STEEL E (×10)

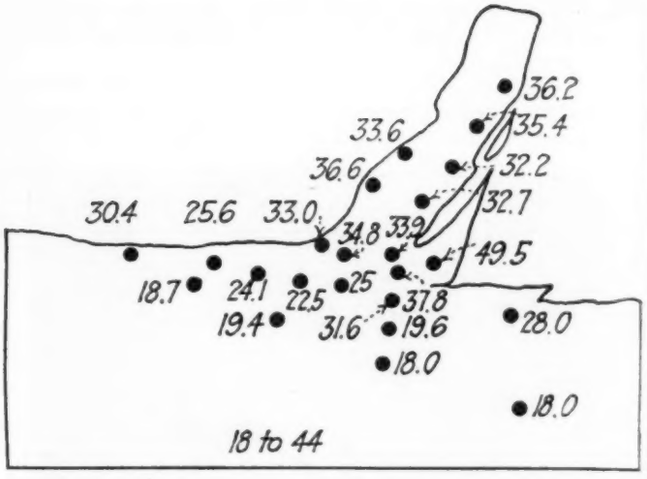

FIG. 5a HARDNESS INDUCED BY TOOL IN STAINLESS STEEL E

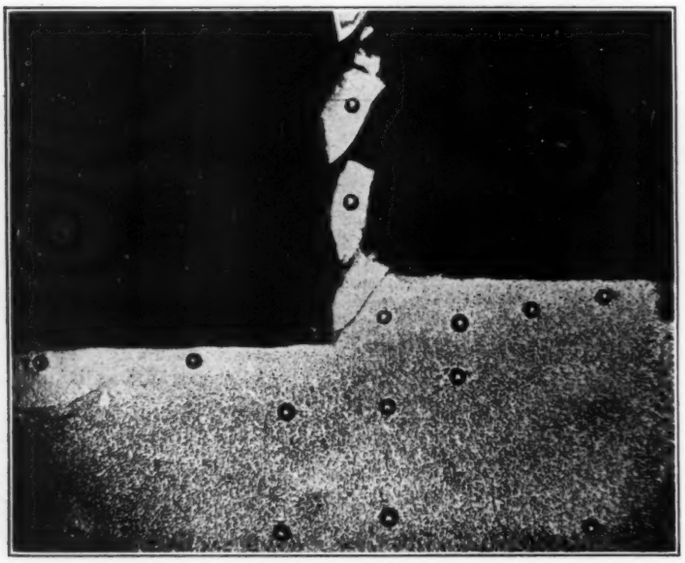

FIG. 6 CHIP IN BRASS F (×10)

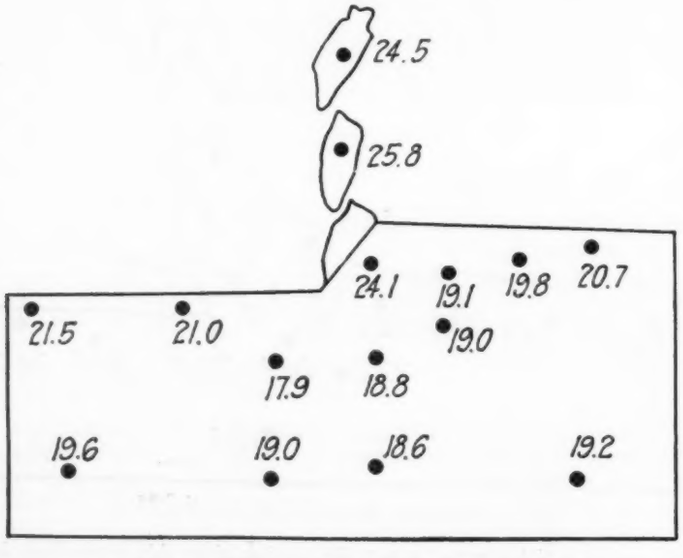

FIG. 6a HARDNESS INDUCED BY TOOL IN BRASS F

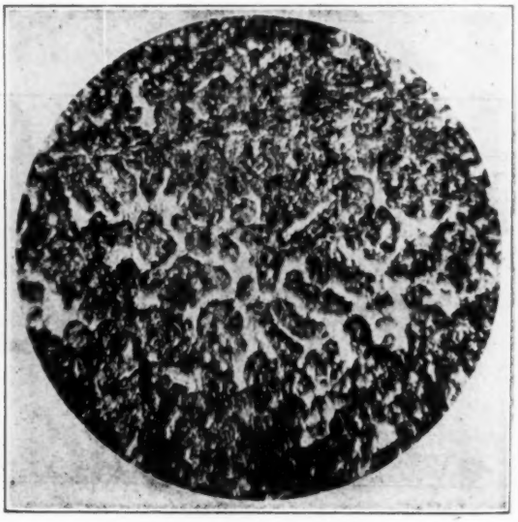

FIG. 7 UNDISTORTED STRUCTURE OF CAST-IRON CHIP. TIME HARDNESS 28.5 (×100)

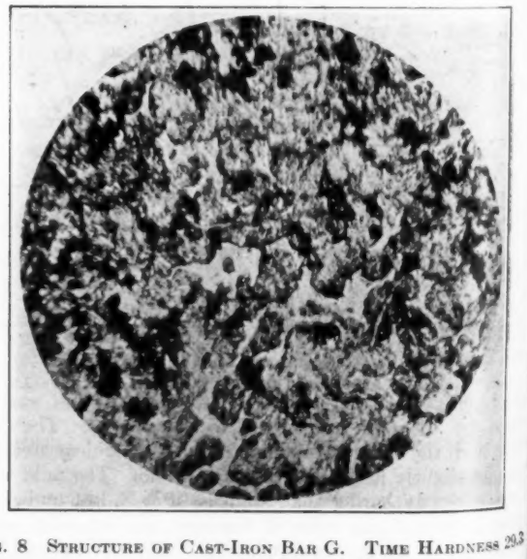

FIG. 8 STRUCTURE OF CAST-IRON BAR G. TIME HARDNESS 29.3 (×100)

force exerted on the tool face tending to cause wear, which depends on the hardness in the path of the tool; the heat generated, which depends on the hardness in the path of the tool, and the ratio between the hardness of the tool and the hardness of the metal in contact with it. Thus the resistance to cutting and the blunting of the tool are governed by the hardness induced by the tool. The original hardness is of little account.

SECTION 2

MAXIMUM INDUCED HARDNESS

The capacity for being work-hardened differs greatly in different metals and the measurement of the hardness induced by cold work is effected by a new method of using the pendulum hardness tester.

FIG. 9 SLIGHT DISTORTION OF STRUCTURE IN BRASS CHIP (×50)

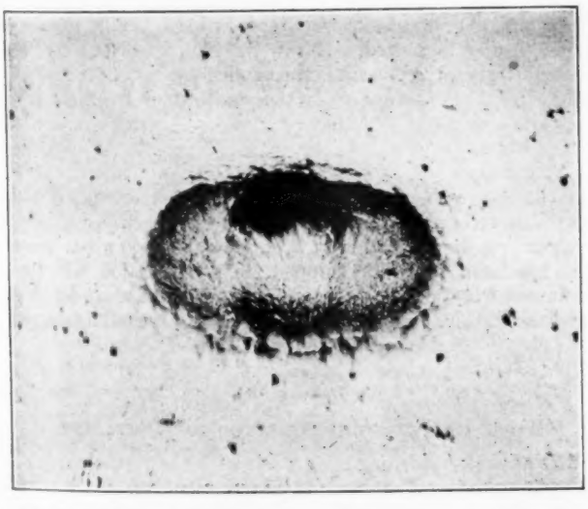

FIG. 10 TIME-WORK-HARDENING TEST IMPRESSION IN MILD STEEL. ORIGINAL HARDNESS, 22; MAXIMUM INDUCED HARDNESS, 29 (×100)

consisting of an arched weight of 4 kilograms supported on a ball 1 mm. in diameter, the center of gravity of the pendulum being 0.1 mm. below the center of the ball (see Fig. 17). When the pendulum is placed gently on a specimen the ball makes an impression exactly like a Brinell impression (see Figs. 1 to 6), and when the pendulum is caused to oscillate through a small angle the ball rolls in this impression without slip and the time period of oscillation measures the hardness of the specimen. The time hardness number is the number of seconds occupied by 10 single swings, a hard specimen and a small impression being indicated by a slow rate of oscillation and a high time hardness number. The pendulum is tilted, while still resting in the original impression, to the right, then to the left, then back to its original position. The effect of these motions is to elongate the impression into the form shown in Fig. 10, to roll the metal by two passes of the ball, and to harden it. The pendulum is now caused to oscillate as before through a small angle while resting in the center of this rolled and hardened surface, and a second time test is made which gives the induced hardness due to two passes of the ball. The effect of this second time test is clearly seen in the bright band in the center of the impression Fig. 10. Just as the size of the original circular impression was measured by the time of swing of the pendulum, so the induced hardness of the rolled surface is measured by the width of this band and by the number of seconds for 10 single swings of the pendulum while resting on it. If the metal has a very high work-hardening capacity, the central band is indistinguishable, just as the impression made by the time test on very hard steel is invisible. The induced hardness due to two passes of the ball having been measured, the rolling process is repeated by tilting the pendulum again to the right, to the left, and back to center. It is invariably found that after a certain number of passes, usually 6 to 10, the hardness reaches a maximum and then declines. Once the maximum has been passed no further increase of hardness can be induced by further rolling. The "maximum induced hardness" is then a measure of the capacity of the metal to be hardened by cold work.

Table 2 gives the readings in "time work-hardening tests" on the metals used in the cutting tests of Section 1, and on other typical metals. The metals differ not only in respect to the maximum hardness they attain, but also in the rapidity with which they attain it.

TABLE 2 TIME WORK-HARDENING TESTS

PASSES OF BALL	0	2	4	6	8	10	12	14	16	18	20
Mild steel A	*21.2*	30.4	30.4	30.7	*31.5*	30.4					
Stainless iron B	*19.6*	*32.5*	31.6	30.4							
Stainless steel C	*19.7*	41.2	45.4	47.3	48.2	49.8	50.3	51.5	52.3	52.7	*52.9* 49.6
Stainless steel D	*27.5*	35.6	35.8	36.3	*36.5*	36.2					
Stainless steel E	*18.0*	38.2	41.9	43.1	*44.0*	43.8					
Rod brass F	*19.4*	*32.0*	32.0	31.8							
Cast iron G	*30.0*	36.4	37.5	38.2	40.6	*40.8*	40.2				
Manganese steel	*21.0*	45.5	52.4	54.0	56.2	*57.2*	44.6				
Hard carbon steel	*71.0*	*89.0*	88.0	86.0							
Aluminum bronze	*22.4*	36.0	40.3	40.6	41.8	*42.3*	40.4				
Aluminum[1]	*5.5*	9.8	10.1	10.3	*10.7*	10.6					
Copper, cast[1]	*6.8*	17.5	19.8	20.8	21.5	23.5	23.5	23.5	23.7	*24.4*	24.4 24.2
Tungsten	*37.9*	56.6	57.9	*58.8*	58.5						

[1]Aluminum and copper were tested with a 3-mm. etched-steel ball to prevent slip.

In Table 3 the steels used in the cutting tests, Section 1, are placed in the order of their maximum induced hardness measured with the pendulum. The hardness induced by the first two passes of the ball is also given and the hardness in the path of the tool and the maximum hardness of the chip from Figs. 1*a* to 6*a*.

TABLE 3 TIME HARDNESS

	Induced by pendulum		Induced by tool		
	Maximum	2 passes	Path of tool	Chip	Original
Mild steel A	31.5	30.4	30.0	36.0	21.4
Stainless iron B	32.5	32.5	32.45	34	19.7
Stainless steel D	36.5	35.6	36.0	39.9	27.2
Stainless steel E	44.0	38.2	37.8	36.6	18.0
Stainless steel C	52.9	41.2	43.0	38.5	19.9

The hardness in the path of the tool is always less than the maximum hardness induced by the pendulum, but approximates to the hardness induced by the first two passes. The order of hardness induced by the pendulum and by the tool is the same, and totally different from the order of original hardness.

The chip hardness presents anomalies, for example, the mild-steel chip was abnormally hard. In this and two other cases the hardness of the chip was greater than the maximum hardness that could be induced by rolling with the pendulum, while in the cases of stainless steels E and C the chip was less hard than the metal immediately in front of the tool. Some of these anomalies may be due to the effect of heat. Cutting was done dry, and the chip attained a temperature which was perhaps sufficient to cause annealing. Since the wear and eventual failure of the tool is normally caused by abrasion of the chip, the ratio between tool hardness and chip hardness must be a principal determining factor

in tool durability. It is not possible to determine the effective hardness of a chip which may have been raised to annealing temperature, but for estimating the hardness which the tool must possess in order to resist the abrasion of a chip, it is assumed that the hardness of the latter is not less than the maximum induced hardness measured by the pendulum test.

From Table 2 it is seen that brass F and cast iron G both possessed a considerable capacity for work hardening. This can have had little adverse effect on their machinability, since they were not hardened by the tool, but under some cutting conditions the work-hardening capacity of such metals exercises a decisive influence, as in filing brass with a blunt file or cutting cast iron with a blunted hacksaw.

SECTION 3

CHIP FORMATION. THE BUILT-UP EDGE

The "built-up edge" on cutting tools is supposed to consist of particles of metal scraped from the bar by the sharp edge of the tool, and accumulating on the top surface of the tool between the actual edge and the point where the chip impinges. The accompanying photographs, Figs. 11 to 16, show the successive stages of its formation and dispose of the popular conception.

Fig. 11 is a chip of stainless iron a few seconds after cutting commenced. A large fissure runs ahead of the tool, and the surface of the chip where it impinges on the tool is dragged back by friction and consolidated into a hard layer whose structure is continuous with that of the chip, except at the upper part where separation has commenced. This confirms the statements of Rosenhain and Sturney (1).[2]

A later stage is shown in Fig. 12 where the first layer has been worn away and overlaid by five successive layers, the last of which is partly continuous with the chip, the separated portion having been broken in withdrawing the tool.

The successive layers are clearly shown in Fig. 13; the edge is assuming its characteristic triangular form and collecting material not only from the chip but from the lower surface.

Figs. 14 and 15 show a later stage where the built-up edge actually surrounds the nose of the tool, while in Fig. 16 the completed edge, built up of innumerable layers and of razor-like sharpness, is cleaving a path through the solid steel. Professor Coker shows (2) that the zone of separation is in tension, and the edge may be regarded as severing metal already stretched to the breaking point.

The built-up edge is the actual cutting implement, the tool merely serving to support it. It is much harder than the metal it is cutting. Thus in mild steel A the original hardness was 21.4, the hardness in the zone of separation 30, the maximum hardness of the chip 36, and the hardness of the built-up edge 44 (440*B*). In stainless steel C the hardness of the built-up edge was 53.4 (534*B*).

As to the manner in which the successive layers are united, Prof. Gerald Stoney has pointed out that welding can take place at quite moderate temperatures between clean metal surfaces under heavy pressure, and it is probable that the edge is a welded structure.

Its cutting angle is much more acute than that of the tool which supports it, and must be assumed to be the angle best suited for cutting the metal under the special conditions in which it is formed. The top rake angle of the tool determines the angle of incidence of the chip, and thus influences the pressure and the rate at which the chip wears away the tool surface behind the built-up edge, this being the ultimate cause of failure of the tool. Dr. Klopstock has proposed (3) to lessen the angle of incidence without unduly weakening the tool by forming a hollow in the upper surface where the chip impinges.

SECTION 4

TEMPERATURES GENERATED IN CUTTING METALS

In a paper (4) on The Measurement of Cutting Temperatures the author has shown that the temperatures generated by tools cutting steel are very high, even when the operation is instantaneous as in the blow of a chisel, or when the tool and the work are flooded with oil or water. For measuring cutting temperatures, the tool and the work being of different metals, as stellite and mild steel, were treated as the two elements of a thermocouple, the tool being insulated with mica, and the thermoelectric voltage generated by the cutting temperature being measured with a millivoltmeter whose terminals were connected to the tool and to a convenient part of the machine.

It will be seen from diagrams in the above paper that a temperature of 500 deg. cent. was generated by the tool taking a cut a thousandth of an inch deep at a speed of 200 ft. per min. when the tool was flooded with water, and a temperature of 700 deg. cent. when cutting dry under the same conditions. On the bar lathe temperatures of over 500 deg. cent. were measured when cutting with oil or water under normal workshop conditions. The instantaneous temperature generated at the edge of a file-cutting chisel was found to be 490 deg. cent., the voltage in this case being measured with a string galvanometer.

The temperature measured by the thermocouple is that at a point of contact between the tool and the work material. Such contact always takes place where the chip impinges on the top face of the tool, a little distance behind the edge, and it does not necessarily take place elsewhere. It is reasonable to suppose that the temperature measured by the thermocouple is the temperature between the tool and the chip, and that this is the maximum cutting temperature. It is the tool temperature and is therefore of supreme significance in relation to the hot hardness of the tool, which, however, is not now under consideration. The temperature in the work material results from the molecular friction due to deformation, increases from a minimum in the undeformed body of the bar, which is nearly cold, through a higher temperature where deformation commences considerably ahead of the tool, and so gradually rising, as the degree of deformation increases, to the zone where separation of the chip commences, rising further as the separated chip is crushed and bent back, and reaching a maximum where the already heated chip passes over the tool under heavy pressure. It is evident then that there is, properly speaking, no work temperature, but a temperature gradient in the work. The separation of the chip takes place somewhere on this gradient, but the actual temperature where separation is taking place cannot at present be measured. It can be inferred with considerable accuracy, but for the present it must suffice to say that the separation of the chip takes place at some temperature intermediate between that of the cold bar and that of the very hot area of contact of chip and tool.

The existence of the temperature gradient may be inferred from the progressive deformation and the gradual increase of hardness illustrated in Figs. 1*a* to 6*a*. Its existence may be demonstrated by observing the coloration of a chip attached to a bar when the lathe has been suddenly stopped. The coloration will be seen to commence in the region ahead of the tool where some deformation has already taken place, and to deepen to a maximum in a portion of the chip which has traveled some distance from the tool.

SECTION 5

WORK HARDENING AS AFFECTED BY TEMPERATURE

In 1923 work-hardening tests made with the pendulum hardness tester on specimens of steel at a series of rising temperatures showed that the work-hardening capacity of the steel declined and sometimes almost disappeared at temperatures between 100 and 150 deg. cent. This phenomenon has been found to be almost universal in steels, and is also found in many pure metals and non-ferrous alloys, usually at temperatures below 100 deg. cent.

The test used in these determinations was the "scale work-hardening test." The pendulum is placed on the specimen in a tilted position with the bubble at 0 on the scale and is released. It swings through a certain angle and stops when its energy has been absorbed in rolling out the original circular impression into an elongated form. The position of the bubble on the scale at the end of this first swing is a measure of the original scale hardness of the specimen, a harder specimen giving a longer swing and a higher reading. The pendulum is then tilted by hand to the left until the bubble is at 100 on the scale and is again released. In this

[2] This and similar numbers refer to the bibliography at the end of the paper.

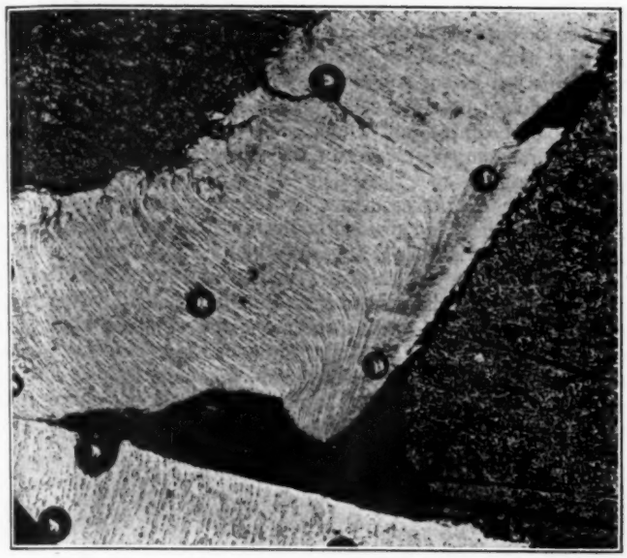

FIG. 11 BUILT-UP EDGE IN STAINLESS IRON B (×25)

FIG. 12 BUILT-UP EDGE IN STAINLESS STEEL (×20)

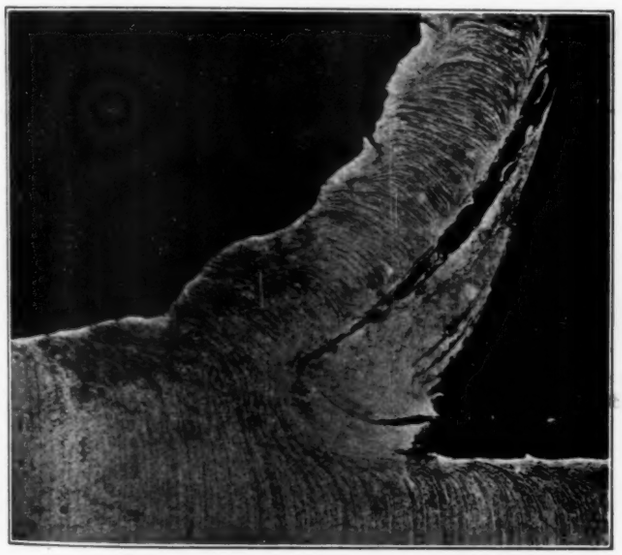

FIG. 13 BUILT-UP EDGE IN STAINLESS STEEL (×20)

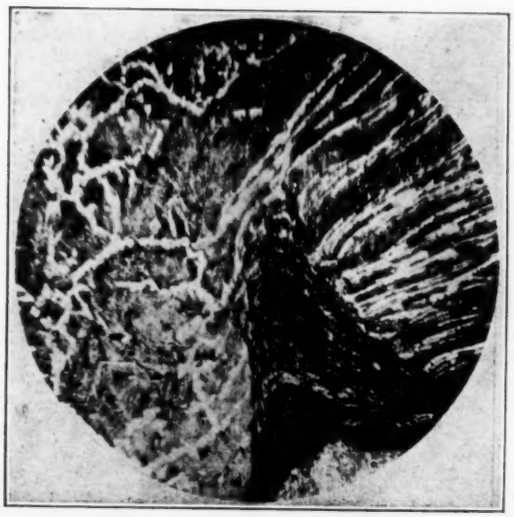

FIG. 14 BUILT-UP EDGE IN MILD STEEL (×50)

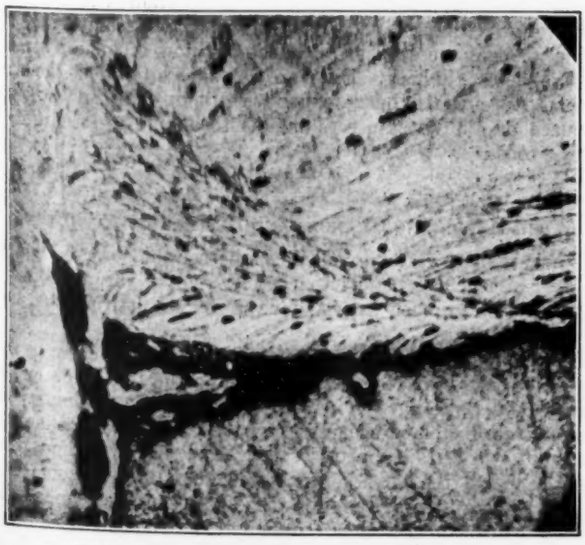

FIG. 15 BUILT-UP EDGE IN MILD STEEL (×75)

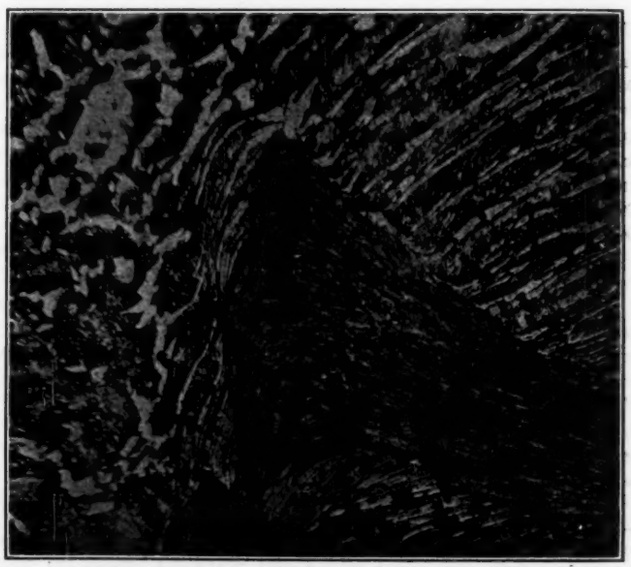

FIG. 16 BUILT-UP EDGE IN MILD STEEL (×100)

case the ball rolls back along the impression which has been elongated, rolled, and work hardened, and the second reading measures the scale hardness of the surface so hardened. The process is repeated until five readings have been obtained. Subtracting the first reading from the average of the next four the number obtained is a measure of the average increase of hardness due to rolling the specimen four times, and is called the "work-hardening capacity" of the specimen. Temperature–work-hardening tests are made with the equipment shown in Fig. 17. The specimen is placed in the electric furnace and remains there during the whole series of tests, which are made at intervals of 5 or 10 deg. Sixty or more tests, each consisting of five hardness measurements, can be made on a surface $1^1/_4$ in. square.

A typical temperature–work-hardening curve is given in Fig. 18[3] for a Vickers test bar steel, containing 0.65 carbon, 0.80 manganese, 0.3 silicon, and is interesting because this steel has been used for the test tubes on which tool steels have been tested during the past 17 years on the Herbert tool-steel-testing machine.

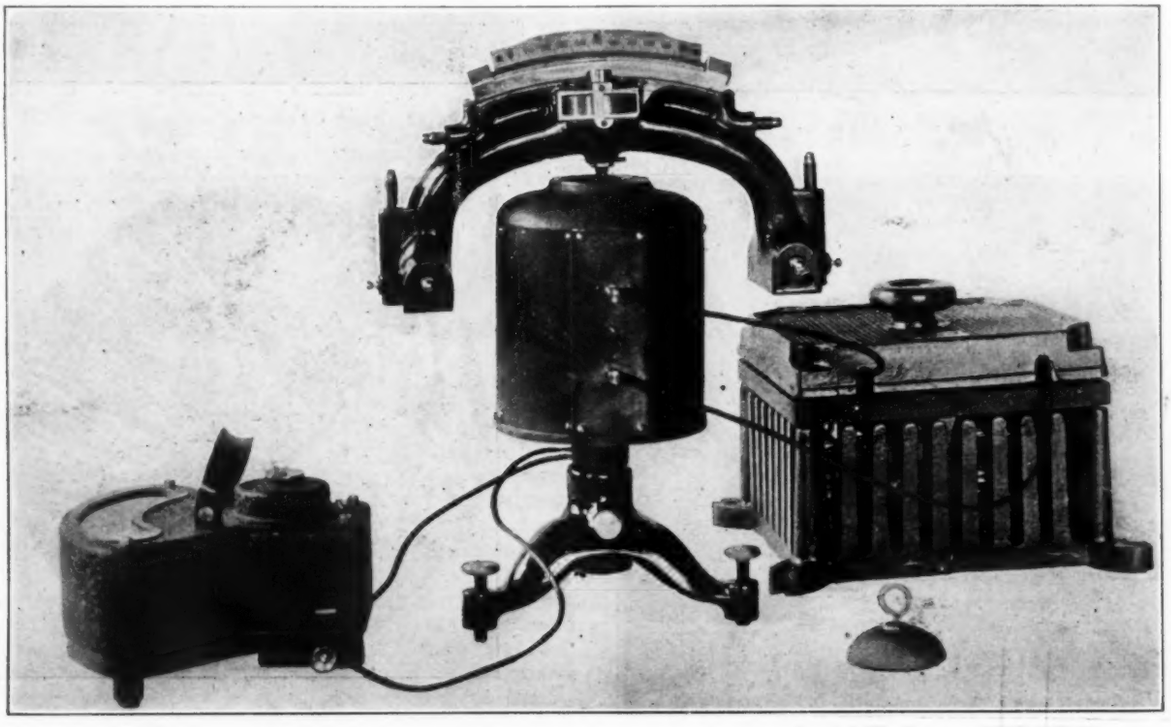

FIG. 17 PENDULUM HARDNESS TESTER AND ELECTRIC FURNACE

In the typical curve Fig. 18 there are six prominent features, three peaks, which are designated P1, P2, P3, and three depressions, D1, D2, D3. The principal depression D2 occurs in steels almost always at 120 to 140 deg. cent., though it has been found in high-speed steel at 150 deg. cent. The curves of the non-ferrous metals are so similar that there is generally no difficulty in identifying the peaks and depressions. D1 is, however, frequently absent, since D2 commences at atmospheric temperature. It is possible that D1 actually occurs below atmospheric temperature.

That phenomena so striking and frequent should have escaped the observation of metallurgists, will appear less remarkable when it is remembered that previous to 1923 the work-hardening properties of metals had not been and could not be measured at a continuous series of temperatures a few degrees apart. The observed changes in work-hardening capacity must, however, be regarded as symptoms of some fundamental changes occurring in the structure of the metals, and it would be strange if these fundamental changes did not influence the results of physical tests other than the one described.

In a paper on the Changes in Iron and Steel below 400 deg. cent., Goffey and Thompson (5) collected from many sources evidence of changes in steel at low temperatures, particularly at 120 deg. cent. and described experiments in which steel wires were subjected to torsion at a close succession of temperatures, and the limit of proportionality was ascertained at each temperature. One of Goffey and Thompson's diagrams is given in Fig. 19 and shows the six features of the temperature–work-hardening curve, three peaks and three depressions, the principal depression corresponding to D2 occurring at 120 deg. Such a similarity of results obtained independently by investigators using different methods of investigation can scarcely be a coincidence.

The question is, "Which of the fundamental properties of metals undergo changes giving rise to these manifestations?" They must be properties common to the structure of the metals in which they occur, atomic, molecular, or crystalline. The evidence points to some changes occurring at the crystal boundaries. It has not been possible to obtain temperature–work-hardening curves from metals in a coarsely crystalline state, because the orientation of individual crystals with respect to the direction of rolling affects their work-hardening capacity and causes erratic readings.

The changes are such as to affect the flow of metals strained beyond the elastic limit. They are not known to affect the structural use of metals, but are believed to exercise an important influence on the resistance of metals to severe deformation by cutting tools.

SECTION 6

WORK-HARDENING CHANGES AND RESISTANCE TO CUTTING

It now remains for us to examine whether the observed changes in the resistance of metals to cutting, and in the durability of cutting tools, are such as would naturally result from the work-hardening changes.

The resistance which a metal offers to a cutting tool can be most directly measured by the vertical force on the tool while cutting. Stanton and Hyde have shown (6) that when the cutting speed is progressively increased the vertical force on the tool declines to a minimum at a certain range of speeds, and rises at higher speeds. The decline in the vertical force was attributed to some effect of the cutting temperature on the steel operated upon. The cutting temperatures were not measured and the particular change in the work material was not identified. Dempster Smith and

[3] In the unabridged paper similar curves are given for mild steel, a very low carbon sheet steel, a free-cutting steel, aluminum bronze, rod brass, sheet brass, aluminum-zinc alloy, and tin.

Leigh (7) made similar tests and arrived at similar results, at a certain range of cutting speeds. It is a fair inference from these two independent investigations that the various steels used in the experiments offered a lessened resistance to the cutting tools when they were within a certain range of cutting temperatures.

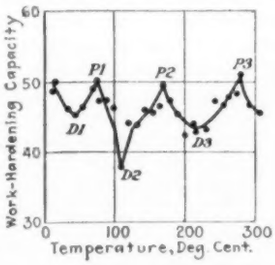

FIG. 18 TEMPERATURE–WORK-HARDENING CURVE OF VICKERS TEST-BAR STEEL

To test this matter further an investigation was suggested by Paul Whitaker. A surfacing cut was made on the end of a mild-steel bar, the cut starting at the center and ending at the periphery of the bar. Thus the cutting speed rose continuously from zero to any desired value, depending on the speed of the lathe. The vertical force on the tool was not measured, but the cutting temperature was measured

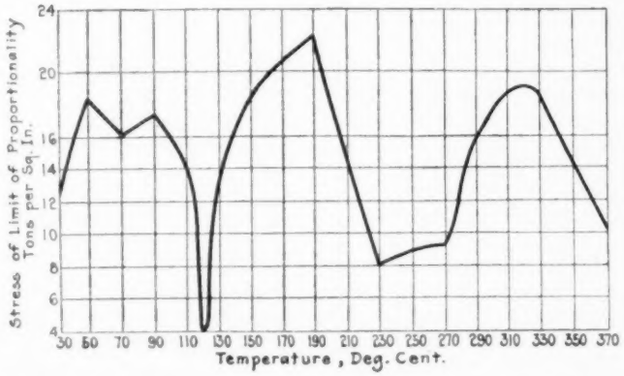

FIG. 19 LOW-TEMPERATURE CHANGES IN STEEL. GOFFEY AND THOMPSON'S TORSION TESTS

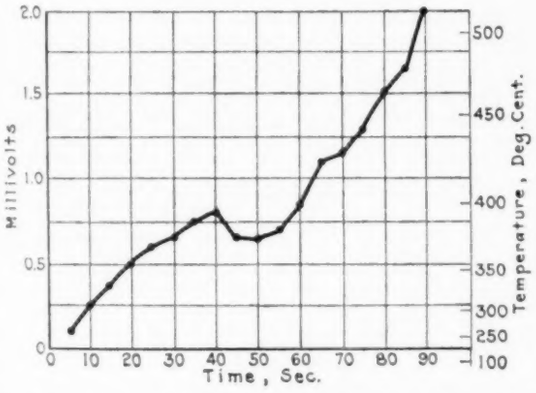

FIG. 20 VOLTAGES AND TEMPERATURE GENERATED IN SURFACING MILD-STEEL BAR

(Surface cut with water; 4-in. mild-steel bar; feed, 170; cut, 0.03; speed, 223 r.p.m.

by the thermoelectric method. The tool was insulated and a voltmeter was placed in circuit between the tool and the lathe. Voltage readings were taken at intervals of 5 seconds during the cut, and one of the resulting voltage curves is given in Fig. 20. The temperatures were ascertained by calibrating a couple made of the tool and a strip of the mild-steel bar. In many such tests the temperature at first rose steadily with the increasing speed, then fell to a minimum, and rose to about 500 deg. cent. at the periphery.

We have here evidence that within a certain range of speeds the generation of heat was less than at higher or lower speeds, and it is only possible to explain this on the supposition that the steel offered a lessened resistance to the tool when it was being cut within a certain range of temperatures.

Fig. 21 is a photograph of the bar on which the surfacing cut was made, and the bright, "Whitaker ring" coincides with the dip in the voltage curve. This familiar ring is certainly a temperature effect; by increasing or decreasing the lathe speed the ring can be produced at a smaller or larger diameter at will. Fig. 22 is a photomicrograph of the outer portion of the Whitaker ring and of the adjacent surface. It shows that the ring is a smoothly finished surface contrasting with the plucked and torn surface outside it. Fig. 23 is a series of temperature–work-hardening curves made with the pendulum on a specimen of steel cut from the 4-in. bar, Fig. 22. It shows the usual deep D2 depression at 135 deg. cent. where the work-hardening capacity of the steel was at a minimum. That the Whitaker ring coincides with the drop in cutting tempera-

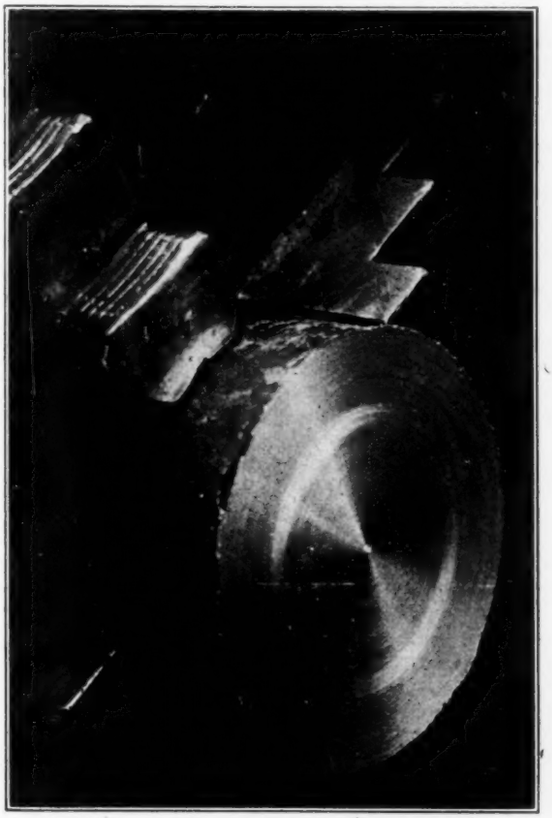

FIG. 21 WHITAKER RING ON MILD-STEEL BAR

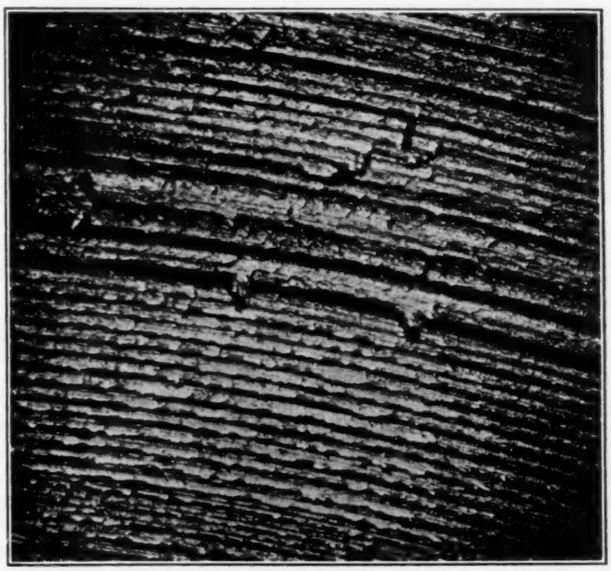

FIG. 22 OUTER EDGE OF WHITAKER RING (×15)

ture was confirmed by observation and measurement. It is believed that the ring, the fall in cutting temperature, and the lessened resistance of the metal to the tool coincide with and are caused by the fall in the work-hardening capacity of the steel at the free cutting or D2 range of temperatures.

It is not possible to prove this by a comparison of temperatures. The significant range of cutting temperatures, Fig. 20, is always higher than the D2 range of temperatures, Fig. 23, but this was to be expected. It was pointed out in Section 4 that the cutting temperature measured with the tool-work thermocouple is the tool temperature, and that this temperature is the highest point of a temperature gradient, rising from the temperature of the cold bar. This being so it is certain that the D2 temperature of 135 deg. cent. occurs at some point in the zone where cutting is taking place, and where the metal is being work-hardened by compression. Any decline in the work-hardening capacity of the metal occurring in this zone must be expected to lessen the resistance to cutting.

A possible clue to the location of the D2 temperature in the cut is given by microscopic examination of the cut surface in and around the Whitaker ring. Observation of these surfaces suggests that the formation of the ring is accompanied by change in the formation or function of the built-up edge. This structure normally performs a role secondary only to that of the tool; the tool acts as a support to the built-up edge, which is the actual cutting implement. If it can be shown that when cutting is taking place at the D2 temperature the built-up edge ceases to function or functions abnormally, it may be possible to say that the D2 temperature occurs at that point on the temperature gradient which coincides with the apex of the built-up edge, that is with the precise zone where the chip becomes separated from the bar. There are, however, formidable difficulties to be overcome before it will be possible to make a section through a chip in the act of being separated from a Whitaker ring, since the ring is associated with a definite temperature and the lathe must be stopped so suddenly as to insure that the chip left attached to the bar has been produced at that temperature.

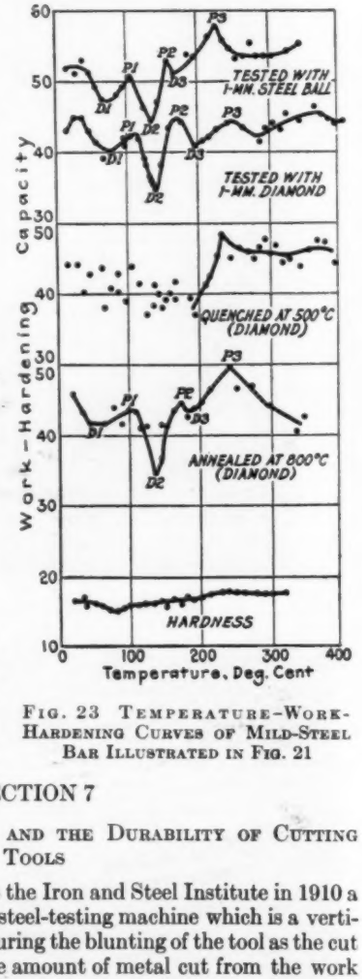

FIG. 23 TEMPERATURE-WORK-HARDENING CURVES OF MILD-STEEL BAR ILLUSTRATED IN FIG. 21

SECTION 7

WORK-HARDENING CHANGES AND THE DURABILITY OF CUTTING TOOLS

In a paper (8) presented to the Iron and Steel Institute in 1910 a description was given of a tool-steel-testing machine which is a vertical lathe with devices for measuring the blunting of the tool as the cut proceeds, and for recording the amount of metal cut from the work piece—a standard steel test tube. The durability of a cutting tool is measured at successive speeds, and a set of speed-durability curves is reproduced in Fig. 24. The characteristics of these curves are the low durability of the tool at low speeds and its increase at higher speeds, and the occurrence of two peaks or maxima. The first of these characteristics is common to the speed-durability curve of every tool that has been tested on these machines in the course of seventeen years, and the second characteristic, the double peak, is of general, though not universal, occurrence. There seem to be only three directions in which explanation of these characteristics might be sought: (1) In some obscure changes taking place in the tool as its cutting speed (and temperature) increased; (2) in some inherent difference between the testing machine and the lathe; or (3) in some changes taking place in the work piece (the test tube) as the speed and temperature increased.

The changes in durability were for many years attributed to unexplained changes taking place in the tool under the influence of cutting temperature, but a fresh difficulty arose when it was found that the same general form of curve was given by tools of carbon steel, high-speed steel, and stellite. Significant fluctuations were known to occur in the hardness and other properties of tool steel under the influence of temperature (7, 10), but these fluctuations were not in themselves capable of accounting for the form of the speed curve, and it seemed wholly improbable that similar changes should take place at approximately the same cutting temperatures in metals so dissimilar in composition as tool steel and stellite.

No essential difference was apparent between the vertical lathe tool-steel-testing machine and the lathes used by engineers such as would account for the peculiar form of the speed curve, and when in 1914 Denis published (9) a large number of speed-durability curves produced on an ordinary lathe and having all the essential characteristics of the testing-machine curves, including low durability at low speeds and the double peak, it became apparent that this form of curve could not be attributed to anything in the design or construction of the testing machine. P. Denis (11) has recently given detailed instructions as to speeds, feeds, and cuts for all

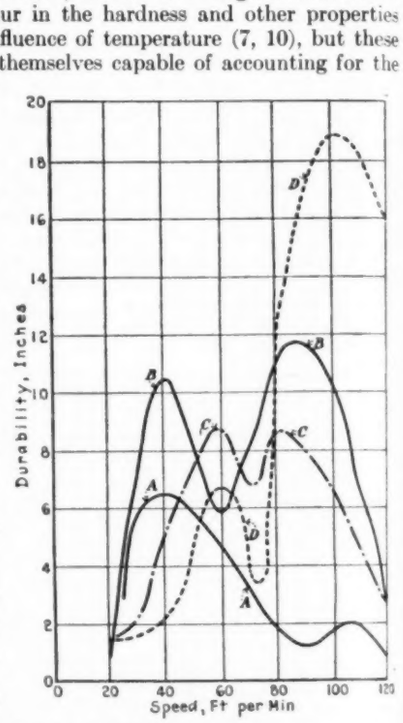

FIG. 24 SPEED-DURABILITY CURVES ON TOOL-STEEL-TESTING MACHINE

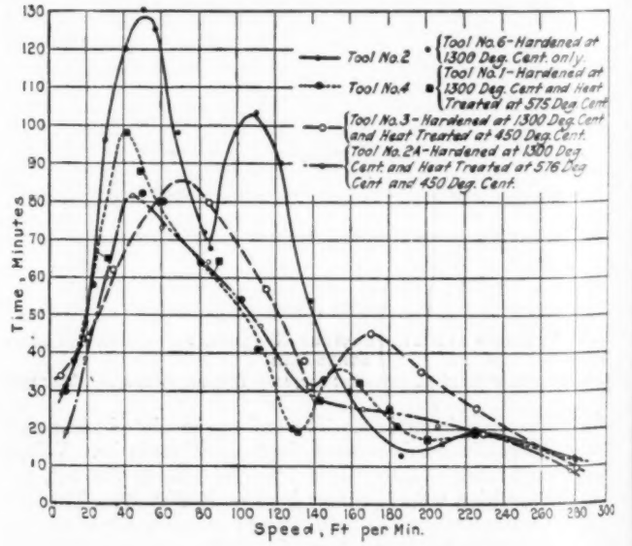
Tool No. 2
Tool No. 4
Tool No. 6 - Hardened at 1300 Deg. Cent. only
Tool No. 1 - Hardened at 1300 Deg. Cent. and Heat Treated at 575 Deg. Cent.
Tool No. 3 - Hardened at 1300 Deg. Cent. and Heat Treated at 450 Deg. Cent.
Tool No. 2A - Hardened at 1300 Deg. Cent. and Heat Treated at 575 Deg. Cent. and 450 Deg. Cent.
Time, Minutes
Speed, Ft per Min.

FIG. 25 SPEED-DURABILITY CURVES ON BAR LATHE

kinds of engineering operations, and all based on his typical double-peaked durability curves with low durability at low speeds. More recently Dempster Smith has conducted an investigation on the lathe (7, 12) and has produced a series of speed-durability curves similar in form to those of the testing machine (see Fig. 25).

That the peculiar form of the speed curve must be attributed to effects of temperature not only on the tool but also on the work material was early recognized, but a review of the known changes in the physical properties of unhardened steels and other metals occurring at various temperatures failed to produce any evidence

of changes at low temperatures which could possibly account for the form of the speed curve. Highly significant changes, particularly in the elongation and reduction of area in tensile tests, were known to occur at temperatures as low as 300 deg. cent. but there appeared to be no important changes at lower temperatures.

It was only when temperature–work-hardening tests were made, first on the steel used by Dempster Smith in his lathe tests (Fig. 25), and later on the Vickers test bar steel used for the test tubes, and later still when Goffey and Thompson's results were brought into review, that light was thrown on the subject. The temperature–work-hardening curve of the test-tube steel is given in Fig. 18; the speed-durability curves produced in cutting this steel, in Fig. 24. If we assume that a tool cutting with water at 20 ft. per min. on the testing machine generates a temperature rather below 100 deg. cent., it will be seen (Fig. 18) that the test tube is then in the condition P1 in which its work-hardening properties are at a maximum. If we now suppose the speed and cutting temperature

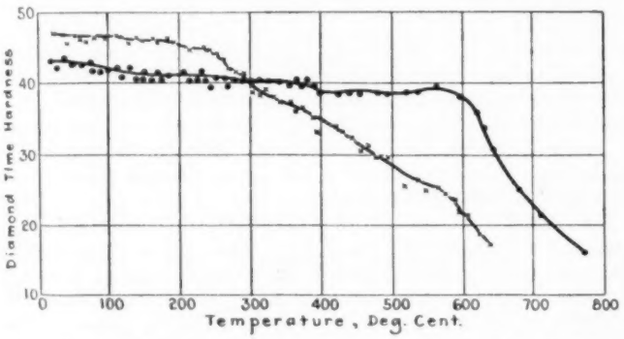

FIG. 26 HOT-HARDNESS CURVES. TOOL A, CROSSES; TOOL B, DOTS

to be raised, and assume, as we must, that a decline in work-hardening of the tube will be accompanied by increased durability of the tool, it is apparent that the speed-durability curve produced on the Vickers steel will be one in which the durability increases from a low value at low speeds to a maximum durability corresponding to the minimum work-hardening at the D2 temperature, and that there will be a second maximum durability corresponding to the minimum work-hardening at the D3 temperature. The speed-durability curves of tools cutting this steel must assume the general form which experience has shown them to assume.

It is not suggested that the durability of the tool and the changes taking place in the tool are of slight importance. The quality of the tool is indeed the predominating influence in the durability curve, whether produced on the testing machine or the lathe, but the features of the curve which are rightly attributed to the quality of the tool must be regarded as superimposed on a curve whose general form is determined by changes in the work-hardening properties of the material operated upon.

While it is true that this consideration introduces an element of complexity into the interpretation of the speed curves, it does not destroy their validity in estimating the quality of cutting tools, since the characteristic changes shown in the typical curve of Vickers steel, Fig. 18, have been found to occur in almost every variety of steel that has been tested, and the principal change, the D2 depression, always occurs in steel at approximately the same temperature, 120 to 140 deg. cent. The behavior of the tool cutting Vickers steel test tube is therefore the behavior that may be anticipated in cutting any other steel.

SECTION 8

PRACTICAL APPLICATIONS

It is not generally practicable to determine the cutting conditions so that cutting takes place in the free cutting range of temperatures, though this may be done in the case of metals which are extremely difficult to cut under any other conditions. There is, however, reason to believe that the form of the work-hardening curve can be modified and in particular that the D2 depression corresponding to the free cutting range can be made deeper and wider by previous heat treatment of the metal, and perhaps by modifying its composition. A metal so treated offers a slight resistance to cutting over a wide range of cutting temperatures and can therefore be cut freely under a wide range of cutting conditions, speed, feed, and depth of cut. This is a subject ripe for investigation by metallurgists.

Although in metal-cutting operations it is not generally practicable to determine the cutting conditions with reference to the D2 range of temperatures, there may be other metal-forming operations, notably presswork, in which, by a suitable regulation of working temperature, advantage may be taken of the D2 decline in work-hardening capacity. This has been found practicable in working certain refractory sheet metals.

Since the limiting factor in the productivity of metal-cutting operations is the inability of the tool to withstand without injury the temperature generated in cutting, an advance in productivity may be sought (*a*) by providing metals which can be cut at higher speeds without generating excessive temperatures, and (*b*) by providing tools capable of withstanding higher temperatures without being softened. These lines of advance can only be followed by studying (*a*) the effect of temperature on the work-hardening properties of metals, and (*b*) the effect of temperature on the hardness of tools.

In order that a tool may cut a given metal, the tool must be harder than the metal, and to avoid undue wear, the hardness of the tool must exceed the hardness of the metal in a certain minimum ratio. The significant hardness ratio is that between the hot hardness of the tool and the work-hardened or induced hardness of the metal. The cold hardness of the tool and the original hardness of the metal have little significance in relation to the ability of the one to cut the other under conditions of high productivity. This can be illustrated by an example taken from practice.

Two tools A and B were required to cut a certain steel X. Their respective cold hardnesses were,

Tool A, dT 47 = 635 Brinell. Tool A was hard.
Tool B, dT 43 = 580 Brinell. Tool B was moderately hard.
Steel X, T18 = 116 Brinell. Steel X was dead soft.

The hot hardness of the two tools is shown in Fig. 26. They were placed in the electric furnace and tested with the pendulum and 1-mm. diamond at temperatures rising from cold to the softening temperatures.

Steel X was tested with the pendulum time–work-hardening test and was found to have a maximum induced hardness 44 equal to 440 Brinell.

At 300 deg. cent. (cutting temperature) tools A and B had equal hardness (see Fig. 25) dT 40 = 540 Brinell. Both were harder than the maximum induced hardness of X (440 Brinell) and would cut it.

At 400 deg. cent. tool A had hardness dT 34 = 460 Brinell, which is little more than the maximum induced hardness of steel X. It could not cut it. Tool B had hardness dT 39.5 = 535 Brinell. It was harder than steel X and would cut it.

At 560 deg. cent., tool A still retained hardness 39.5 (535 Brinell). It would still cut steel X. Tool B was quite soft.

The inference is that the hard tool A would be incapable of cutting the dead-soft steel X except at slow speeds. The softer tool B should be capable of cutting steel X at quite high speeds, but would wear rapidly owing to the rather low tool work-hardness ratio. A tool having higher hot hardness would be desirable.

Tool A was a hacksaw blade containing 2 per cent tungsten.
Tool B was a hacksaw blade containing 18 per cent tungsten.
Steel X was stainless steel.

Both blades were set to cut stainless steel dry at 146 strokes per minute. Blade A failed in a few seconds. Blade B made several cuts, during which it became red hot, but blunting was somewhat rapid.

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Discussion

R. S. KERNS[4] pointed out that the paper did not tell the method of cutting the specimens described in its first paragraph. This cutting of the specimen, together with the polishing operation seemingly would have a tendency to work-harden the surface of the specimen. The author had attempted to show that a machine operation on metal would work-harden the surface of the object as well as the metal in the path of the tool. If the machine operation had work-hardened the specimens, then the values shown in this paper on increased hardness were not true values due to the tool alone, but resulted from a second work-hardening process. Hence the values over the area investigated were not all based on the same conditions. According to Table 3, the hardness of the specimen in the path of the tool was approximately the same as that produced by two passes of the pendulum. The double cold-working process produced by the tool and the subsequent cutting of the metal as described in the first paragraph, gave time hardness numbers almost identical with those produced by two passes of the pendulum, which was also a double cold-working process.

There was no doubt that the metal was hardened by the tool in making a cut. However, it was doubtful that the values shown by the author were the true hardness numbers of the metal caused by the tool alone. If these values were high, then how could it be shown what the true hardness was when subject to the working tool and to no subsequent work hardening?

The author had reported on only one shape of tool. Would a different shape of tool nose work-harden the metal in the same manner? Or, would a tool with an increased rake have a tendency to work-harden the surface of the specimen or the metal in the path of the nose of the tool as did the tool described?

Jos. K. Wood[5] quoted a letter from the Brown-Bailey Steel Works, Ltd., of Sheffield, England, in which they made the following statement in reference to properties of steel D, whose time-hardness was given in Table 3: "This steel machines fairly easily and may be said to be closely comparable in machining properties with heat-treated nickel-chrome steel of 55 to 60 tons tensile strength." In regard to steel E, they made the statement: "It is more difficult to machine E than steel D, and requires a higher speed and slower feed. It can be turned more easily than it can be drilled. Care has to be taken not to allow the tool to rough on the work surface and increase machining difficulties."

In regard to steel C, the corresponding statement was made: "Similar remarks apply as to steel E. It is a little more difficult all around to machine than E. From experiments other than cutting tests, we have determined that steels E and C do work-harden much more rapidly than steel D, and that steel C work-hardens more rapidly than E, and it is for this reason that we manufacture steel E in preference to steel D."

R. Poliakoff[6] wrote that the author had shown numerically the changes in hardness that took place in the metal lying in the path of the tool that was cutting it. He showed that this induced hardness affected the process of cutting, and the life of the tool. If now, instead of considering the durability of the tool, as did the author, we considered only a predetermined or predescribed uniform condition of wear or bluntness of the tool, and took longitudinal cuts on a bar in a lathe at increasing speeds, the result must be that the lengths of the surfaces cut would follow the author's curves of durability and temperature–work-hardening curves. This conclusion naturally followed, if the author's deductions were correct, that the induced hardness was influenced by the temperatures at which deformation occurred, and changed with the cutting speeds.

Tests by the writer confirmed this conclusion. In making finishing cuts in a lathe on a steel bar, both with carbon and high-speed-steel tools, it was found that the lengths of surfaces machined with increasing speed follow a curve similar to those of the author. If the quality of the finish at different speeds could be represented on a diagram, the latter would have a form similar to the curve giving the relation between cutting speeds and surfaces machined. The phenomenon would be similar to the Whitaker ring described by the author, the ring being translated from a plane, as in the paper, into space. It is quite probable that on a bar of very large diameter, a second Whitaker ring probably would be observed, although of a different degree of brightness.

The author had mentioned a hollow in the surface of the tool as proposed by Dr. Klopstock. As a matter of fact, this was proposed by the writer at the Cincinnati meeting of the Society, eight years before Dr. Klopstock proposed it.[7] The theory then advanced for this proposal was based on the formation of elementary, i.e., very thin chips, of which the actual chip can be imagined as consisting. These thin chips must cause internal friction, displacement, and also heat formation.

The author in closing said that Mr. Kerns was concerned about a possible work-hardening effect due to the process of cutting the sections. In all metallographic work it was so much a matter of routine to adopt extreme precautions to avoid any disturbance of the metal under observation, such as might be caused by the process of section cutting, that it was not considered necessary to describe the process in detail. The sections were cut in the first place with a fine-toothed hacksaw. A considerable thickness of metal was then removed from the cut surface by careful hand polishing on coarse emery paper. All the metal affected by the coarse emery was then removed by hand polishing on emery paper of a finer grade, and this was repeated with emery papers of increasing fineness, followed by a final polishing with rouge and immersion in weak acid to dissolve the polished surface.

The ordinary process of preparing specimens for hardness tests was essentially one of section cutting, and no special precautions such as those detailed above, were taken against work-hardening effects. It might therefore be doubted whether any hardness figures had ever been published which were less likely to have been affected in the manner suggested by Mr. Kerns, than those to which he referred.

Mr. Kerns was correct in stating that only one shape of tool was used in the experiments, though an exception was made in the case of the tool used for cutting brass. This tool had zero top rake in accordance with the usual practice in cutting that metal. Preparations were being made for further experiments in chip analysis in which it was proposed to use acute-angled tools such as were commonly employed on the bar lathe, but no actual results had yet been obtained.

Mr. Poliakoff had given valuable confirmation of the peaked character of the durability curve of a tool cutting at increasing speeds, and especially interesting was his evidence that the peak of the durability curve coincided with a maximum in the quality of the finished surface produced by the tool. This not only added an important link to the chain of evidence connecting the D2 depression in the temperature–work-hardening curve with the peak in the durability curve and with the smooth finish of the Whitaker ring, but also showed that the ring phenomenon might be turned to practical advantage by selecting the critical cutting speed which gave the maximum durability to a finishing tool, and the smoothest finish to the work.

His surmise that a second ring might be observed was correct. It not infrequently happened that three distinct rings occurred, and it was believed that these were produced at cutting temperatures corresponding with the D1, D2, and D3 depressions in the temperature–work-hardening curve.

[4] Penna. State College, State College, Pa.
[5] Consulting Engineer, New York, N. Y. Assoc-Mem. A.S.M.E.
[6] Mechanical Engineer, New York, N. Y. Mem. A.S.M.E.
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The High-Speed Oil Engine

Some Notes on Design, Research, and Shop Practice

By H. F. SHEPHERD,[1] GROVE CITY, PA.

THE TERM "high speed" may today be applied to oil-burning engines operating at mean piston speeds up to 1500 or 1600 ft. per min., well above the traditional speed of 750 to 900.

There is, strictly speaking, no "school" of high-speed oil-engine designers as yet. Automotive engineers, having a supply of gasoline still available at a fair price, have not in any great numbers studied injection. It has consequently fallen to the lot of Diesel-engine designers to acquire the necessary training to build engines to operate at high speeds. The demand for these engines arises from the markets; it is not the result of promotion, and may be regarded as a healthy product of the times.

In Fig. 1 are shown, superimposed, a slow-speed oil-engine shaft

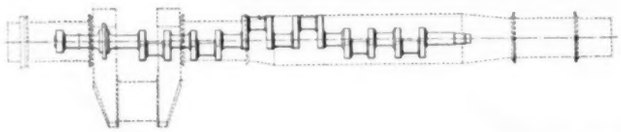


FIG. 1 COMPARISON IN SIZE OF SLOW-SPEED OIL-ENGINE CRANKSHAFT WITH ONE FOR A HIGH-SPEED GAS ENGINE OF THE SAME RATING

which the author put into use five years ago and the shaft of a high-speed gas engine of the same rating, upon the design of which he acted in a consulting capacity a year later. To bridge a gap of this sort, the habit of analysis is useful, for much that is true of the one type holds conversely for the other.

After rigid test by the customers, several of these high-speed gas engines were delivered in two-, four-, six-, and eight-cylinder types, operating at speeds from 720 to 900 r.p.m. and rated at from 50 to 200 b.hp.

With this experience as a basis, most of the past three years has been applied to research in the design of high-speed oil-burning engines. The research, the shop practice, and even the economics of the situation have proved to be somewhat at variance with the author's established views, built up on twenty years' previous experience with heavier engines, and the following notes from experience are offered.

COMBUSTION

Increasing the speed of the Diesel engine has brought out nothing novel thermodynamically.

If testing reveals anything it is only the necessity for wearing surfaces of genuine high-grade workmanship, for first-class metals properly heat-treated, and the general design practice already well established in the automotive field.

The advance of injection for high-speed is little if any greater than for slow-speed engines. The natural turbulence of the air charge seems to be stronger even at the same valve-passage air velocities. This may be so because less time has elapsed to damp it. This was a pleasant surprise and removed the fear that the time interval would be too short for combustion.

Maximum pressures tend to run higher and it is well to design for 750 lb. rather than for 600 lb. This is true of the airplane engine as well. Old-time gasoline engines were designed to resist 400 lb. per sq. in., but 750 lb. is not uncommon in the airplane engines of today.

PROBABLE LIFE

The most conscientious efforts will be required if the life of the high-speed engine measured in revolutions is to be as great as that of the older slow-speed engine. Forces due to rotation and reciprocation increase directly as the square of the number of revolutions. It is not always practical to increase strength or surface to carry these greater loads as mass increase overcomes any advantage. In the case of the valve gears, improvements can be made in design, workmanship, and lubrication of the pin bearings; but connecting rods and pistons have already been developed as regards bearing metals and lubrication to the best of our present knowledge, so that reduction of weight is essential. If this is carried too far, life will be short, of course.

COST PER HORSEPOWER

It is quite obvious that a high-speed engine will cost less per horsepower if, using smaller but adequate dimensions, it is constructed of the same materials as are used for heavy engines; let us say, gray iron, S.A.E. 1020 steel for case-hardened parts, and S.A.E. 1035 steel for forgings.

If extra-light weight is a further requirement, aluminum or steel castings replace gray iron for the main structure. Aluminum alloys can replace at the most three times their weight of cast iron, and usually but twice. Their cost will be not much less than 60

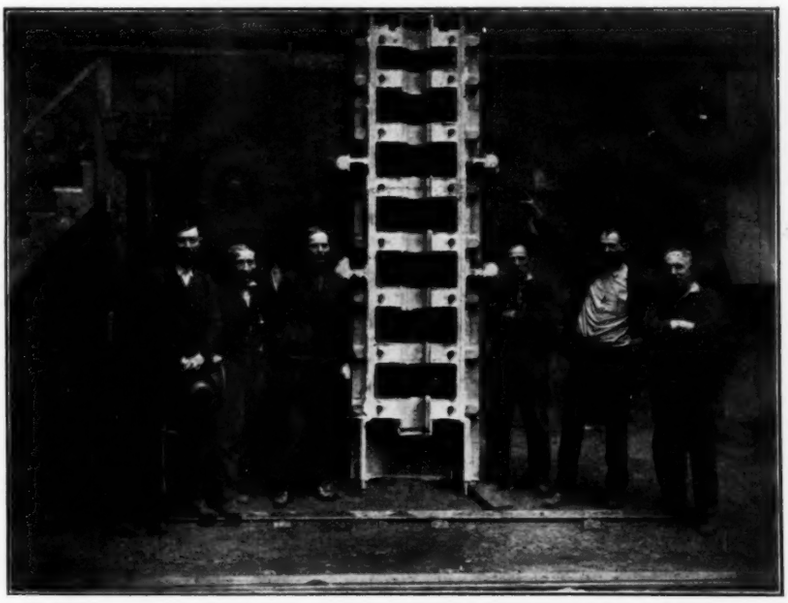


FIG. 2 OIL-ENGINE BED OF CAST ALUMINUM

cents per lb. Multiplying iron-foundry costs or prices by two or three will by no means offset this figure. Steel castings for bed plates are not definitely quoted but have been tentatively offered at 25 cents per lb., with reservations for future orders. Such castings have been made with sections half as thick as would be used confidently in gray iron, but their use is still not economical and the supply is as yet uncertain. Malleable-iron bed plates are being made in numbers for engines of moderate size but the foundries are not yet ready to undertake anything larger. The annealing equipment is not large enough and distortion causes either too many losses or the expense of too much care to make the job a very profitable one.

Thus there are high-speed engines designed with a low-price objective and high-speed engines built for the least possible weight. Fortunately the light engine in aluminum may be built to the same design as the heavy engine, so both aims may be met with only a price difference. Fig. 2 shows an aluminum bed cast in the Bessemer foundries from the regular patterns.

[1] Diesel Engineer, Bessemer Gas Engine Co. Mem. A.S.M.E.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, February 25, 1927.

DESIGN

Regardless of what cost considerations may govern the main structure, the weights and designs of the reciprocating parts, piston and rod, are fixed by the speed, although two strings of parts, a light set for high speeds and a heavy set for more moderate speeds, may be used with the same engine design. Fig. 3 shows a 16-in. aluminum piston used for higher speeds in place of the used gray-iron piston. Experience has shown that the mean terminal inertia should not exceed 100 lb. per sq. in. of piston area. It is true that

FIG. 3 16-IN. ALUMINUM PISTON FOR HIGH-SPEED OIL ENGINE

the rods of double-acting engines are put in far greater tension, but the inertia load is a result of mass which is a measure of the shock at pressure reversal. An examination of airplane engines of all types shows that designers have reduced piston weights so much in attaining inertias below this figure that piston life is a matter of hours.

Assuming that

$$0.00034\ WrN^2 = 100$$

then for 250 r.p.m. and 750 ft. piston speed, $W = 6.3$ lb. This engine may be built with a crosshead.

For 600 r.p.m. and 900 ft. piston speed, $W = 2.2$ lb. This engine may be built with a quite substantial cast-iron piston and a steel rod.

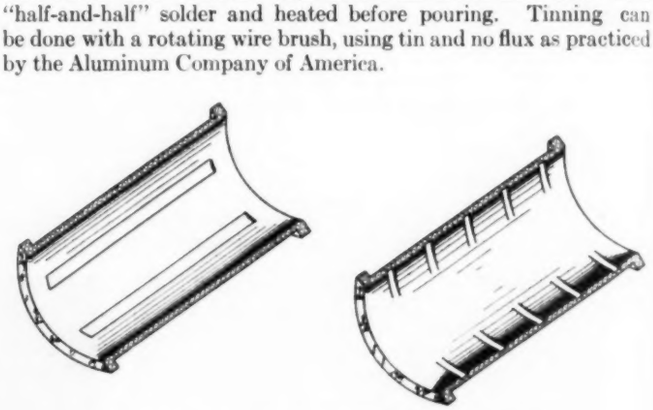
For 800 r.p.m. and 1600 ft. piston speed, $W = 0.92$ lb. This engine may be built with a sturdy light-metal piston and a well-designed steel or duralumin rod.

For 1200 r.p.m. and 1600 ft. piston speed, $W = 0.61$ lb. Here far greater skill will be required to attain the weight and at the same time provide ample strength and proper wearing surface.

Piston speed after all is not a rational measure. Piston speed times revolutions is the true measure of inertia forces. A high mean piston velocity reached by a long stroke results in far less free force than the same piston speed resulting from high revolutions. Here the designer must consider the driven machine. High generator or centrifugal-pump cost or the introduction of a speed-increasing drive may put the unit off the market although the engine price is favorable. It is always well to design for synchronous speeds, say, 600, 720, 900, and 1200 r.p.m., as pumps and other machinery are so designed for motor connection.

Rotating parts, although balanced, deserve special consideration; both crankpin and crankshaft bearings are split horizontally.

Stationary-engine bearings are usually well relieved at the joints, and thus fitted they are not well adapted to horizontal loads. At mid-stroke, when any crank is horizontal, inertia forces are about zero and there is no gas pressure except the negative work of charging or exhausting. This leaves the box and crank almost totally under the influence of centrifugal force operating in a horizontal direction on the box joints. Fitting to a high bearing helps this condition, also grooving as in Fig. 4 or Fig. 5, but it is always advisable to reduce the force. This is done by babbitting directly into the steel rod, using as little babbitt as possible on account of its high specific gravity; or by the use of duralumin rods. The author has used, quite successfully, a conventional tubular forged-steel rod with a conventional crankpin box of aluminum alloy lined with babbitt. The box is first "tinned" with aluminum solder and then with "half-and-half" solder and heated before pouring. Tinning can be done with a rotating wire brush, using tin and no flux as practiced by the Aluminum Company of America.



FIGS. 4 AND 5 GROOVING FOR BEARING BUSHINGS

Cast-aluminum-alloy pistons are worth about one dollar per pound, and the equipment cost is high. If the other engine parts are suitable for increased speed, their use by permitting higher speed and rating in the ratio about $\sqrt{2}$ to 1 = 1.41 to 1 is economical. They are perhaps not as durable as cast-iron pistons in normal use, but in case of too close fitting or overheating they are far less likely to ruin liners by scoring or to pull rods apart by piston seizure. The crown must be supported as the metal does not retain its strength above 600 deg. fahr. It is also very elastic and of coarser structure than gray iron, and therefore fails by fatigue if subjected to frequent flexing at high temperature. The Butler piston with its steel bands overcomes any expansion difficulties.

FIG. 6 FORGED DURALUMIN PISTON ROD

Forged duralumin rods are very attractive. The high cost of dies has prevented the author from testing them until recently, and perhaps there has been some reluctance in accepting the empirical designs advanced by the makers. The modulus of elasticity of this metal is low, and constants for use in Rankine's column formula would be very welcome. Vickers has already done much of this work for the design of airship members, but nothing applicable to rods. The set in use (Fig. 6) is wonderfully attractive and seemingly unbreakable. It is used on a 500-hp. V8 Bessemer engine.

For the same reason that the "rotating" end of the rod should be light, the crankpins should be as light as possible, particularly as two throws operate on the center bearings, but due consideration must be given to torsional stiffness. It was once considered practical to pass through one or more critical speeds in the operating range, avoiding continuous running at these speeds. Today, in rotating and reciprocating machinery, critical speeds are avoided altogether. Short shafts of large dimensions are the order of the day. Crankpins should be hollow to reduce centrifugal weight and the moment of inertia of the shaft weight. Light, stiff shafts and light reciprocating parts are most effective in raising torsional critical points. The *pv* values are raised by short bearings of large diameter, but no case has been found where any near approach to a limit has been reached. The *pv* value as a factor of engine-bearing design has lost significance with the exclusive use of forced lubrication. By the use of the babbitt metal developed by the Bureau of Standards, maximum pressures as high as 1750 lb. per sq. in. have been placed on the crankpins without trouble. An oil-temperature curve for an engine using this metal at this pressure is shown in Fig. 7. No cooler was used. The installation was in a room which seldom had a lower temperature than 85 deg. fahr.

Thus far no crankshaft dampers have been used on Bessemer engines, and the stiffness of the shaft is proportioned from the known critical speeds of other shafts in engines of similar design.

The following statement by C. E. Summers[2] is perhaps more nearly true than anything that has been written on the subject.

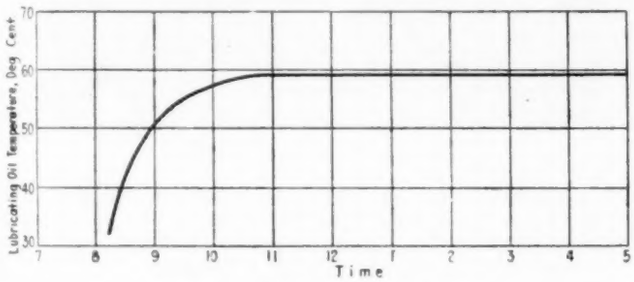


FIG. 7 OIL-TEMPERATURE CURVE

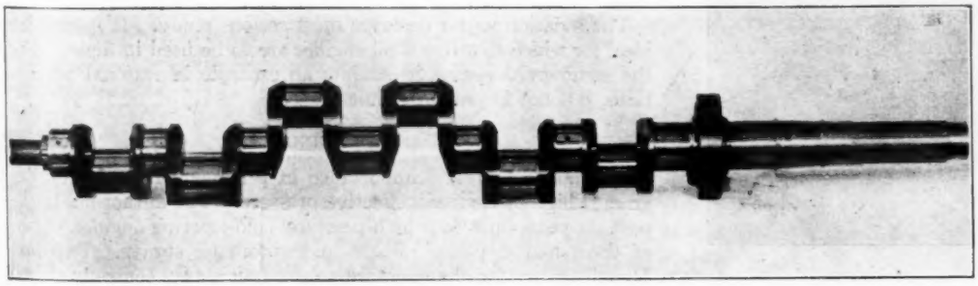


FIG. 8 CRANKSHAFT FOR PACKARD AIRPLANE MOTOR

The complexity of the problem becomes apparent when we attempt to determine by calculation the amplitude and frequency of the torsional vibration of a given crankshaft. The solution requires an accurate pressure-volume and pressure-time indicator diagram, the piston and connecting-rod weights, the crankshaft rigidity in bending and torsion for each section, the effective moment of inertia of the crankshaft at every pin, the relative phase of the vibration wave with respect to position, the piston friction, the bearing condition, and, perhaps, other data. The variables introduced in the gas-pressure characteristics caused by distribution, spark advance, and detonation may result in 100 per cent difference in the amplitude of vibration and, owing to the irregular shape of a crankshaft, its simultaneous distortion by bending and to centrifugal and torsional forces, having assembled with it the rods and pistons, which vary throughout the revolution in effective moment of inertia—it is not possible to calculate the natural rate of vibration of the shaft assembly with even approximate accuracy.

Because of the necessity for great torsional stiffness, stresses run very low in these long shafts, so there is little use for alloy steels.

We cannot do better than to examine carefully the new Packard airplane-motor shaft (Fig. 8) for an impression of ruggedness and of short, stiff bearings before proceeding from slow-speed engine shafts into the design of high-speed shafts. We must always bear in mind that to double its natural frequency the shaft must be four times as stiff. A Bessemer V8 shaft designed by Professor Lewis for 800 r.p.m. is shown in Fig. 9.

Experiments with models show that a shaft with flying cheeks will be as stiff torsionally as a shaft with a bearing between each cylinder if the same weight of metal is used but not so for the same dimensions. Such shafts will perhaps be little used as they are not readily forged for six cylinders, although they are quite easily made for four or eight cylinders.

If the lightest possible engine is required, the hung shaft is an essential feature of the design. Two sets have been tested and the type is preferred if properly designed. Bearings are perhaps more easily fitted and replaced from above or below than in the conventional type in sizes up to about 9 in. bore.

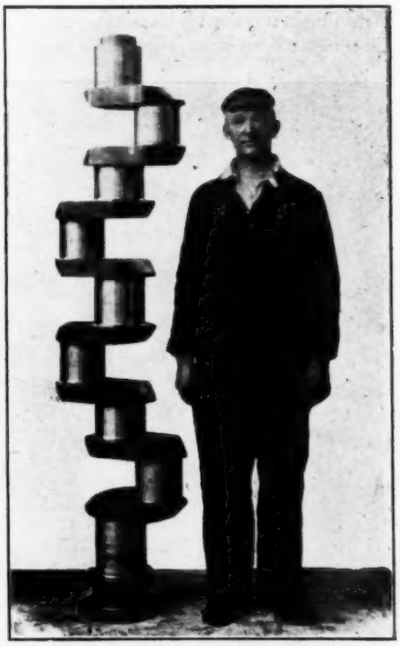


FIG. 9 CRANKSHAFT FOR BESSEMER OIL ENGINE

Dual valves are necessary in designing Diesel heads for high-speed engines. At 800 to 1000 ft. per min. piston speed all the available space in the combustion-chamber crown for single valves has been used. With dual valves there is no difficulty in allowing room for a central spray and in devising valve gears that will follow the cams up to 1200 r.p.m. with a spring tension not exceeding 12 to 15 lb. per sq. in. of valve area, figures that have long been in use. The camshaft should be elevated, but it need not be over the cylinder heads to interfere with inspection or repair. The entire profile of the cam should be designed, of course.

The valve-gear drive deserves special mention. Priority in the use of chain drive for high-speed oil engines cannot be claimed, although such drives are an almost essential feature of the type. Caution must be exercised in designing the drive and in selecting the chain. The author's practice is to lay out a torque curve for single cylinder first. This is then superimposed as many times as required for the number of cylinders served. Variations in timing among various engines and variations in cam and roller proportions and the mechanical advantage of sprockets over the cam make rules of thumb dangerous. Fig. 10 shows what is perhaps the first Diesel "silent" chain drive in the United States. There are in production today drives for fast engines ranging from 80 to 1500 hp. The authors' company prefers to use a pinion and two-to-one gear at the crankshaft. Fuel pumps are driven from the gear. The chain drives valves and sprays only. The chain sprockets may then be of equal size, and the great sprocket at the cam shaft is avoided.

SHOP PRACTICE

The most significant points in shop practice necessary to high-speed work are the reversion to the practice of lapping and the enlargement of grinding operations. Breaking-in large high-speed engines with a motor is not satisfactory. They should be so fin-

[2] *S.A.E. Journal*, February, 1925.

ished that little "wearing in" is required. Ground or "honed" cylinders may be run in under their own power without scoring iron pistons or damage to aluminum-alloy pistons. This is by no means uniformly possible with bored or reamed cylinders with small clearance. Both ground and honed cylinders have been used at high speeds with great satisfaction. Fig. 11 shows a $17^1/_2$-in. cylinder with the hone used beside it. The process is a truly corrective one.

Lapping has also been extended to cam rollers and pins, to pump plungers, spray needles, and even to valve seats, with great satisfaction. Valve seats have been produced holding 4000 lb. fuel pressure without any hand grinding whatsoever. No great amount of training is required if the simple governing principles are followed. The scheme is to start a job with almost 100 per cent bearing surface rather than to assemble parts gaged over high spots only to find them too loose after they are run in, also to avoid much hand fitting, which causes engines to vary in service or performance with the fitter's skill.

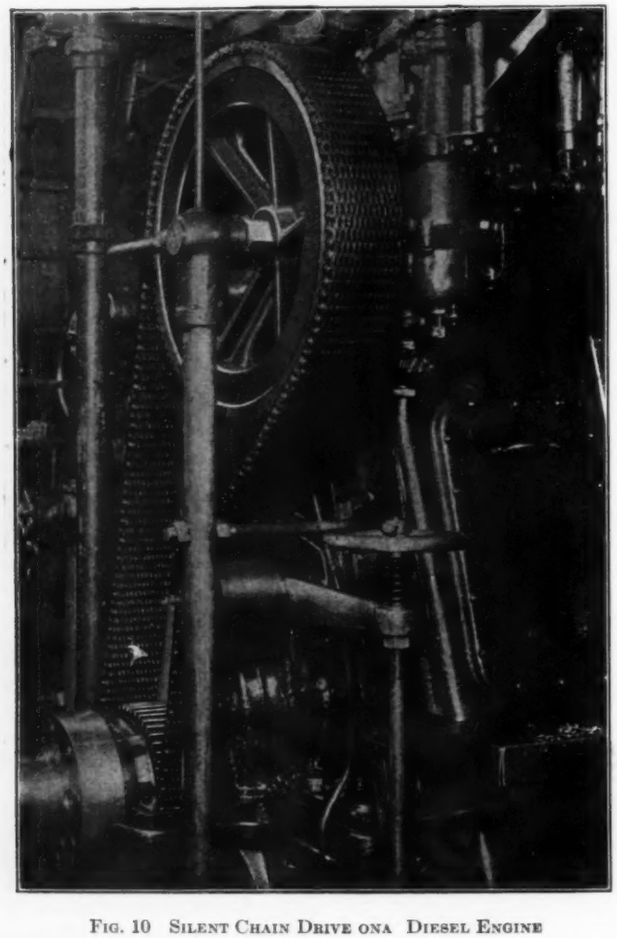


Fig. 10 Silent Chain Drive ona Diesel Engine

Engine Weight

The probable weight of a design is too often underestimated. One recent engine, which according to the prospectus should have weighed 30 lb. per b.hp., actually weighed 60 lb. Another engine was actually delivered at a very low weight but is now being redesigned because the aluminum heads did not stand the service.

Most of today's efforts are centered in engines of 7 to 9 in. bore. It is the author's experience based on actual estimated designs that serviceable engines will weigh about as follows:

At 600 r.p.m., all iron and steel with bed plate, 70 to 90 lb. per hp.
At 600 r.p.m., all iron and steel with hung shaft 40 to 60 lb. per hp.
At 600 r.p.m., aluminum and steel, 25 to 30 lb. per hp.
At 900 r.p.m. weights should be about inversely proportional.

The great discrepancy between airplane-engine and oil-engine weights is caused by these factors:

600 to 1200 r.p.m. against 1200 to 2200 r.p.m.

75 to 100 lb. brake m.e.p. against 135 to 150 lb. brake m.e.p.

Detachable heads and cast-iron liners against closed heads and steel liners with valve seat in forging and passage and guides in head

Flywheel to meet electrical guarantee against no flywheel

Box or block engine frames for stiffness in lengths up to 12 ft. against sheet-metal jackets.

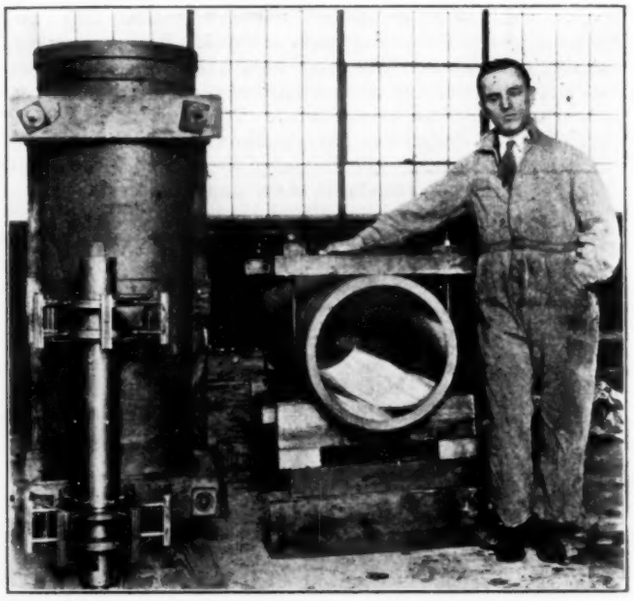


Fig. 11 $17^1/_2$-In. Cylinder Liner with Hone Beside It

Reasonable wear and safety factors and no organized servicing against a life of 40 to 50 hr. before the top overhaul and a major overhaul after four minor overhauls

Salvaged after three to four major overhauls

Cost a major consideration against cost secondary to flight requirements.

The aviation motor deserves most serious study. It marks the ideal for which to strive if oil engines are to be used in flight. For the commercial engine it exhibits an example in rational proportions, but not in practical dimensions.

Rating

One factor of prime importance in producing light-weight engines is high brake mean effective pressure. The author has in the past six years built four high-pressure, cold-starting engines. Two of them had displacer pistons and automatic sprays. Two had Diesel combustion chambers with automatic sprays centrally placed in the head. In direct comparison to these he has undertaken for his own education a series of tests on a line of Diesel engines which have the Diesel form of combustion chamber with cam-operated sprays. Rated at the point of best economy the brake-mean-effective-pressure capacities of the types are: Displacer-piston engine, least; Diesel with automatic spray, intermediate; Diesel with cam-operated spray, highest. What type of injection system is to survive the test of high speed is not yet shown, but very certainly the cam-operated spray sets the pace for high rating and freedom from detonation trouble.

The possibility of the complete gasification of coal at the mouth of a mine and transmission direct to large industrial centers through pipes has been brought much nearer to realization by operations in the West with natural-gas pipe lines in which gas has been transmitted as much as 450 miles under high pressure. The distance from the Pennsylvania bituminous coal fields to New York City is a little over 300 miles. An 18-in. pipe capable of delivering enough gas to supply the entire New York City territory could be built for an estimated cost of $15,000,000.—*Power*, July 12, 1927, p. 71.

Wave Power

Description of a Machine Which Is Claimed to Meet Essential Requirements and for Which the Author Predicts an Efficiency of 60 Per Cent

By LYBRAND SMITH,[1] WASHINGTON, D. C.

THE two main difficulties which lie in the way of using wave energy are its irregularity and its low quality or concentration, by which is meant the relatively low power available from a cubic foot of water in a wave when compared, for example, to that in a cubic foot of water at Niagara.

The obvious and practical way to overcome the first difficulty is first to receive the energy as it comes from the wave, second, to convert it into *potential* energy in an accumulator, and finally to utilize this energy as required. The obvious accumulator of potential energy in this case is an elevated reservoir of water.

It is to overcome the second difficulty—the low quality or concentration of energy—and the change of form of wave energy from *kinetic* to *potential* energy that is the subject of invention.

Requirements of Wave Machines

A practical machine for the purpose of extracting energy from sea waves must have the following fundamental characteristics:

a It must be a rugged structure

b It must be of simple form with few moving parts. (Both requirements are obvious to one familiar with the destructive force of sea waves)

c It must be capable of vertical adjustment for height of tide

d It must be capable of horizontal adjustment when, on different days, the waves break at different distances from the shore because of the effect of different tides or winds[2]

e It must convert the *kinetic* energy of the wave (the form in which most of the available energy exists) into *potential* energy with a minimum loss

f The receiving end of the machine should be in deep water where the waves have more power; while the operating end should be in shoal water (or on land) where the waves will not cause damage.

The machine described in the following paragraphs meets all of these requirements.

The Machine

The chief element of the proposed wave motor is a mechanism known as the hydraulic ram.

Referring to the diagrammatic sketch in Fig. 1, *A* is a hydraulic ram showing the waste valve, the non-return valve, and the air chamber. Leading straight out to sea is a *long* and approximately horizontal drive pipe *B*. The length of the drive pipe not only permits the ram to be mounted back of protection inshore, while the open end of the drive pipe is in the powerful waves of deeper water, but also increases the efficiency, as it is well known that the longer the drive pipe the greater the water hammer or excess dynamic pressure which causes the ram to lift water.

A flow of water in the drive pipe is set up by the impulse from the waves. Some of this impulse comes from the static pressure due to the height of a wave above mean water level, but this is trivial compared to the dynamic pressure available in the moving water of the waves.

Many people make the mistake of thinking that the water in waves has considerable movement of translation. Actually, except in very shallow water, there is little or no translation of the water. Instead the water particles move in more or less elliptical orbits—the motion in the upper part of the orbit being in the direction of the wave. For example, the velocity of a wave 4 ft. high and 96 ft. long in water 10 ft. deep is 16.7 ft. per sec., but the velocity of the surface particles of this wave in their elliptical orbits is only 2.7 ft. per sec., and the velocity of particles below the surface grows less with their depth.

Evidently, if the open end of the drive pipe were exposed to the wave a slight impulse would be given to the water in the pipe, but by mounting a funnel at the end of the drive pipe with its mouth exposed to the waves the low velocity of about two feet per second will increase. Such a funnel is shown at *C* in Fig. 1 with its open mouth at *D*. The floor of the funnel is raised at *E* to form a dam, the purpose of which is to keep the drive pipe completely full of water.

To provide for machines of such dimensions that the inertia of the column of water will not prevent its rebounding seaward

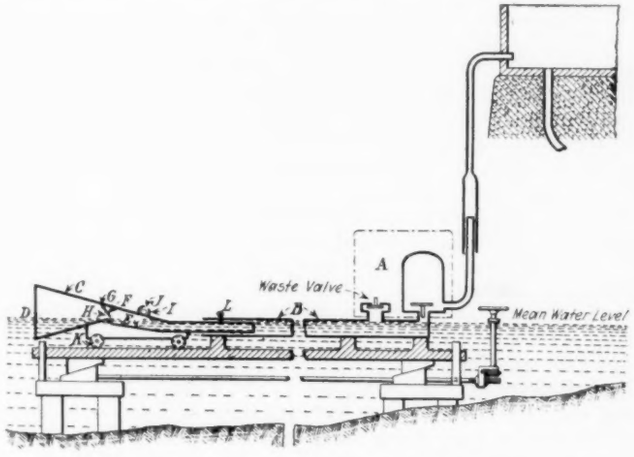


Fig. 1 Diagram of a Device for Using Wave Power

over the dam, a rebound, or "flap" valve is provided at *F*, pivoted at *G*, and stopped at *H*. It is believed that this valve could be eliminated where the drive pipe was long enough.

To provide for the escape of imprisoned air a vent is made at *I* and fitted with a hollow ball *J* (held in place by a wire mesh) as a valve. Several points are to be noted regarding this air vent and valve:

a Its direction is such that it will tend to "scoop" the air from the top of the air and water stream

b The valve closes by *gravity*, i.e., the ball floats when the funnel is filled by a wave—and this is an advantage, for where the velocity is greatest the static pressure is least. Its action is independent of either static or dynamic pressure

c The outer part is such that a wave passing over will not imprison air and force it into the machine. Water might be forced in, but not an appreciable amount of air.

How It Works

Starting with everything at rest, the drive pipe full of water, the waste valve open at the shore end, the air-vent valve open at the sea end, a wave strikes the open funnel mouth. The water particles are prevented from continuing in their elliptical orbits and go forward in the funnel gathering speed as they go. Any air trapped ahead of the wave goes out the air vent until the funnel is full of water; then the valve floats and the vent is closed. Meanwhile, the impulse of this stream or jet through the funnel imparts acceleration to the water in the drive pipe.

Now suppose that the waste valve is adjusted to close suddenly when some velocity v is reached. The question arises, will a very

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[1] Lt-Commander, U. S. Navy. Bureau of Engineering, Navy Department.

[2] This is not to intimate that such a machine should be put in the breakers. On the contrary, it should be kept out of them. The breakers are merely used here as a reference point to explain the necessity for horizontal adjustment.

small acceleration produce this velocity? It will if the acceleration is continued long enough—if the time available is long enough. In the case of a wave motor, however, the time intervals will not be of indefinitely long duration, but will be limited to approximately one-half the time intervals between waves. Therefore for a given apparatus it is evident that a wave below some definite force and time interval will not pump water, but neither will it produce a sudden shock or stress on the machine as the energy of such a wave is used overcoming the inertia and friction of the water in the drive pipe.

Proceeding now to larger waves, it is evident, for an apparatus of a given size, that when the waves attain some particular force and time interval, the force will produce the required velocity v in the time interval available, the waste valve will close, and the sudden checking of momentum caused by this closure will produce the water hammer, or excessive dynamic pressure, required to raise some water through the ram to the reservoir.

In the case of a stronger wave with a longer time interval, the greater impulse will cause the water in the drive pipe to attain the velocity v in less time. This greater acceleration, and the longer time interval of a bigger wave will enable the water to attain the velocity v more times per wave. That is, the waste valve will operate more times per wave as the waves grow more powerful and longer.

Every time the waste valve closes, the mass of water in the full drive pipe, its velocity, and therefore its momentum, will be the same. If this momentum is always checked in almost exactly the same time (the time taken to close the waste valve, a fraction of a second), a certain definite water hammer should always result and throw the same amount of water to the same height. The apparatus gains power with more powerful waves by having more water hammers per minute.

How do these facts affect the accumulation of potential energy in this machine? Say the weakest wave which will operate it at all (i.e., produce one impulse per wave) will produce an impulse just sufficient to lift water 106 ft. and that the storage reservoir is at 100 ft. This means that each impulse would waste 6 ft-lb. of energy per pound of water; but since the individual water hammers are just the same for a strong as for a weak wave, the storage accumulating efficiency should remain the same through a wide range of wave sizes, the limiting size for maximum efficiency not being reached until a huge storm wave appears which is so powerful that one impulse succeeds another before the former dies out, or until all impulses merge into one, the waste valve being driven tight shut and the water simply squirting through the machine. In such a case the efficiency would decrease. For all practical purposes, however, it may be said that the efficiency of the machine remains at a constant maximum throughout its operation, regardless of variations in wave power.

The Adjustable Features

Normally any wave machine must be capable of adjustment for height of tide. Of course, such machines in use on the Great Lakes could do without this feature and even on some sea coasts the rise and fall of the tide is so slight that the additional cost of installing the apparatus in a manner capable of vertical adjustment might not be compensated by the increased efficiency. Between great rise and fall of tide and no tide would be cases where it might be practical to raise and lower only the seaward end of the apparatus, leaving the ram at a constant level. In such cases the great length of the drive pipe should permit the bending of the pipe through the small angle required without straining it beyond the elastic limit.

Because it depends upon local conditions the method of raising and lowering the machine is purposely shown in the drawing as a crude arrangement of sliding wedges as the object is merely to show that vertical adjustment should be made. Hydraulic jacks, operated by hydraulic power from the storage tank and controlled automatically by a float rising and falling with the tides but protected from wave action, might be used in a large machine.

The horizontal adjustment feature is also merely shown in a simple manner as the actual design will depend on size of machine and local conditions. In the sketch the funnel is shown mounted on rollers K and locked for any particular adjustment by a set-screw L. No means (other than hand power) is shown in the sketch for moving the funnel. Horizontal adjustment of the funnel might be effected by horizontal hydraulic jacks controlled by hand from shore.

Horizontal adjustment is necessary because on different days with different winds and tides the waves break at different distances from the shore. As it is considered inadvisable to have the funnel mout hactually in the breakers, the horizontal adjustment should be provided unless the water is so deep that the waves will never break in the vicinity of the funnel mouth.

Power Available

If E be the number of foot-pounds per foot of wave front and N be the number of waves per second, then EN is the energy in foot-pounds per second per foot of wave front, and $EN/550$ is the horsepower per foot of wave front.

When not observed directly, N may be taken from the fundamental wave formula

$$N = V/L$$

where V = velocity, and
L = wave length.

Furthermore, V may be computed from the formula

$$V = C\sqrt{5.123L}$$

in which V is in feet per second, and L is in feet, while C, which is a coefficient equal to the square root of the ratio of the axes of the elliptical surface orbits, may be determined from the following table,

d/L =	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
C =	0.552	0.746	0.888	0.922	0.958	0.977	0.988	0.994	0.997

in which d is the depth of water, or distance from the center of the surface orbit to the bottom, and L the distance from one wave crest to next. (It is only necessary to use C where the depth of water is less than one-half the wave length.)

The formula for horsepower per foot of wave front thus becomes

$$\frac{EC\sqrt{5.123L}}{550\,L}$$

As L is a directly observable quantity, it only remains to determine E from the formula for salt-water waves in shallow water:

$$E = 8\,LH^2\,(1 - 19.74a^2/L^2)$$

where E = foot-pounds in one foot of salt-water wave front
L = length of wave in feet
H = height of wave in feet
a = semi-major axis of surface orbits and may be determined in terms of the wave height H from the following table:

d/L =	0.10	0.15	0.20	0.25	0.30	0.35	0.40
a =	0.91H	0.68H	0.59H	0.55H	0.52H	0.51H	0.504H

Substituting this value of E in the horsepower formula, we get

$$\frac{8LH^2(1 - 19.74a^2/L^2)C\sqrt{5.123L}}{550L} = 0.0357675CH^2(1 - 19.74a^2/L^2)\sqrt{L}$$

as the horsepower[3] of one foot of wave front of height H, length L, in water d feet deep, the depth affecting the factors a and C.

The length of a wave for any given height, or vice versa, depends upon wind, sea, and complex local influences, but given heights of 2, 4, 6, 8, 10, and 12 ft., the lengths 66, 96, 126, 156, 186, and 216 ft. will, under general conditions, correspond to the respective heights sufficiently closely for a practical calculation to show the power available. Using these heights and the corresponding lengths, the horsepower per foot of wave front has been calculated for water 10, 20, and 30 ft. deep with the results as shown in Table 1 and in Fig. 2.

A four-foot wave in water 30 feet deep, a very moderate and

[3] The fundamental formulas and tables necessary for the above deductions can be obtained from Merriman's American Civil Engineer's Pocket Book.

TABLE 1 HORSEPOWER PER FOOT OF WAVE FRONT

Height, ft.	Length, ft.	Horsepower per foot of wave front in water 10 ft. deep	20 ft. deep	30 ft. deep
2	66	0.99	1.15	1.16
4	96	4.12	5.15	5.45
6	126	9.29[1]	12.33	13.58
8	156	16.59[1]	22.10	25.58
10	186	24.64[1]	34.96	41.48
12	216	...	50.66[1]	61.29

[1] Breakers.
NOTE: Above values are for waves in *salt* water. For fresh-water waves reduce horsepower by 2½ per cent.

usual condition, has 5.45 hp. per foot of front or 28,816 hp. per mile, and furthermore, a small increase of height produces a large increase of power.

EFFICIENCY

While it is more or less idle to discuss the efficiency of a machine prior to its final design, a preliminary idea may be obtained as to whether its fundamental principles would permit a high efficiency in good engineering practice. The probable efficiency could well be discussed under four headings:

a The mouthpiece (a cone)
b The drive pipe (a long tube)
c The hydraulic ram
d The accumulation of potential energy.

It is believed that a high efficiency could be obtained in the mouthpiece and that the efficiency should increase with the size of the apparatus when both entrance and exit become larger. Furthermore, where a very long drive pipe is used it is believed that the rebound valve could be eliminated, which would also eliminate loss of head by shock on that valve. Sufficient experimental data are not available to predict accurately the efficiency of the mouthpiece, but considering that most of the energy of a wave is in its upper part and studying data at hand regarding flow through cones, fire nozzles, and jet propellers, it is believed that by good design an efficiency of 90 per cent could be obtained.

The efficiency of the drive pipe would depend largely upon the loss of head in that pipe. As the nature of the machine easily permits a straight drive pipe, loss of head at curves would be avoided. Since the loss of head due to friction is directly proportional to the length of the pipe the loss of head would increase with the length; on the other hand, the dynamic pressure in the drive pipe when the ram operates would increase with the length, and it is believed that the efficiency due to increased dynamic pressure would more than offset that lost through friction due to length of pipe. As loss due to friction is inversely proportional to the diameter of the pipe, the bigger the machine the less the loss, the diameter of the pipe increasing faster than its length. The friction loss increases nearly as the square of the velocity, but the adjustment of the waste valve practically controls the velocity in the drive pipe and therefore the principles permit a maximum efficiency of design, taking into consideration the friction loss due to increased velocity on one hand and the increased dynamic pressure due to increased velocity on the other hand. The friction loss increases with the roughness of the interior surface; good workmanship and good care should keep this loss very low. It seems reasonable to predict that an efficiency of 90 per cent could be obtained in the drive pipe.

From data on the efficiencies of hydraulic rams, it seems not unreasonable to expect an efficiency of 80 per cent for this part of the machine. Merriman mentions a ram used experimentally which had an efficiency of 92 per cent, but does not say by what formula this efficiency was computed.

While the data in the paragraph regarding accumulation of energy were arbitrarily assumed, they are entirely reasonable, and show that the efficiency of accumulating potential energy might well be 94 per cent.

Using these four principal factors in the efficiency of the machine, it seems not unreasonable to predict that approximately 60 per cent of the kinetic energy of waves could be accumulated in the form of potential energy for use as required in standard hydraulic or hydroelectric machines. Such a prediction, under the circumstances, can hardly be little more than a good guess, but its purpose is to obtain a preliminary idea in regard to the advisability of undertaking further investigation and actual development.

DISADVANTAGES

Some disadvantages and objections to the proposed machine and the answers to them follow:

a It is an undeveloped machine.

The purpose of this paper is to interest engineers in the development of wave power. The same objection would apply to any new machine. In view of rising cost of coal, the increasing use of electricity, and the location of the best water-power sites far inland, it is thought that the commercial prospects warrant the development.

b The first machines would probably have poor efficiency.

The estimated efficiency is more than sufficient to warrant a trial, and even a minor success with such a machine would cause

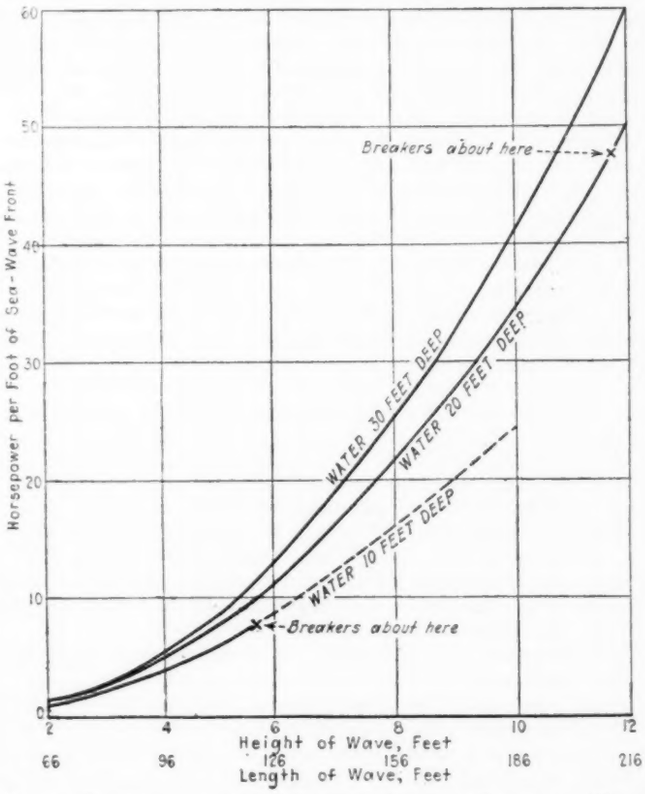

FIG. 2 HORSEPOWER OF SEA WAVES IN VARIOUS DEPTHS OF WATER

further development by attracting the interest of some of the best engineering brains and skill.

c The first cost of installation would be high as compared to the first cost of other hydroelectric plants.

A reasonable comparison of the first costs of the two kinds of plants should include every item from the preliminary survey to the cost of the electric transmission lines supplying ultimate consumers of power. These items can well be divided into three groups as follows:

GROUP 1

Cost of preliminary survey of site
Cost of preliminary investigation of power available at site throughout the year
Cost of site
Cost of transportation of materials to site and labor of erecting them
Cost of impounding reservoir
Cost of electric transmission lines from plant to consuming centers.

GROUP 2

Cost of delivery pipes and drive pipes
Cost of hydraulic rams
Cost of mouthpieces
Cost of adjustable features
Cost of piling on which to mount apparatus.

GROUP 3

Cost of standard hydroelectric machines.

Every item of Group 1 is common to both plants. It is believed, however, that an estimate for practically any definite location would show that the cost of every item in this group is *less* for a wave-power plant than for the usual plant. This is particularly true of the costs of transportation and erection, reservoir, and transmission lines, with special emphasis on the last item in the case of supplying power to the large centers of population near the sea coast. The items of Group 2 are an extra charge not imposed on the ordinary power plant. It is probable that they would cost more than the saving which could be effected in Group 1. The item in Group 3 is identical for two equivalent plants and should be considered in making up the total in order to determine the percentage by which the grand total first cost of one plant would exceed that of the other. It is probable that the cost figures would show a relatively small percentage working against wave-power plants—in their early development at any rate.

d Exposure to storm waves would damage the machine.

The recent success of using an "air breakwater" to protect exposed harbor works by breaking up storm waves with air bubbles renders this difficulty easy to overcome. The machine itself could furnish the small power required to pump the air under such circumstances.

e Exposure to ice would damage the machine or interfere with its operation.

Any hydraulic plant exposed to extreme cold would suffer a similar disadvantage. On most of the United States coast there would be little interference from ice.

ADVANTAGES

The main advantages of this machine are the following:

a It fulfils the fundamental requirements of a wave motor as stated at the beginning of the paper.

b Its fundamental principles permit the development of comparatively high efficiency and do not hold the machine to low efficiency (as, for example, in extracting power from coal the fundamental principles of a steam engine hold its efficiency comparatively low).

c The motive power (waves) is free—which means low operating cost.

d The power of the installation can be increased indefinitely simply by adding unit after unit, all pumping into the same reservoir. Each new unit can be of latest design without interfering with the others. Multiple units enable one to be overhauled while others are working.

e The best sites for development are exposed bluffs on the sea coast, which are mainly waste land now. They are consequently cheap.

f When built near used land such a machine would tend to protect the coast behind it by causing the energy of the waves to do useful work in a machine instead of destructive work on a shore or harbor structure.

g The first cost would be reduced by easy transportation of materials coastwise as compared to difficult transportation of materials in mountainous regions.

h It would use water power now wasted, and would use it near localities which need it now.

i It would not compete with inland water power as the field is broad enough for both without conflict of interests—particularly since the power sites are mutually exclusive.

j It would not cause competition by tidal power plants, as the best places for tidal power are the worst for wave power, and vice versa. Where both could operate they would be mutually helpful, each one tending to boost the other.

k Preliminary surveys are unnecessary. If any part of the earth is well charted it is the coast line.

l Reliable meteorological data are available for all coasts. To determine, for example, the force and direction of the wind prevailing at any place during any month consult a "Pilot Chart" of the U. S. Hydrographic Office. The force and direction of the winds will affect the size and power of the waves. Examine the winds up to 1000 miles off shore. Remember waves approach practically parallel to the coast regardless of direction of wind.

m The development of such a machine would not conflict with the interests of the large manufacturers of hydraulic or hydroelectric apparatus. Instead it would directly help their interests by affording an increased use for their present standard apparatus.

CONCLUSION

It is believed that the above discussion suggests the method of building a practical, reliable machine for utilizing wave power. The changing of the suggested method into actual practice is a challenge to competent industrial engineers.

The Strength of Cast Iron

IN A paper on The Strength of Cast Iron, before the Institute of British Foundrymen, J. E. Fletcher (consultant to the British Cast Iron Research Association) pointed to the disturbing fact that considerable variation in tensile, transverse, torsional, compressive, and impact tests must be looked for in a group of test bars cast simultaneously from the same ladle of metal in similarly prepared molds cooled at equal rates. In many hundred of bars of various sizes and of varying chemical composition, tested by different workers, the values recorded for the tensile and transverse breaking loads in any one series of bars of similar size and approximately similar composition varied considerably from the mean of the series. He did not intend to convey the idea that the range of strength variations made it impossible to arrive at a practical working mean in any particular narrow range of cast-iron compositions, but, in view of the developments taking place in cupola melting practice, and in the methods of casting and cooling the pieces, he sought to call attention to some of the possible causes of those variations.

The dominating influence of silicon and total carbon together, and the importance of the carbon and silicon proportions in the T.C. + Si factor must have first attention when attempting to interpret the analysis of a cast iron in terms of its mechanical strength. The influence of total carbon, silicon, manganese, and phosphorus were related to Brinell hardness values. There, again, the sum of the total carbon and silicon contents were shown to be of great importance. The modulus of rupture stress in transverse tests, when considered in relationship to the ultimate tensile strength yielded a valuable factor, Tv/T, which played an important part in a study of the strength of cast iron. That factor was related to the deflection, to the sum of the total carbon and silicon contents and to the relationship of carbon to silicon in that sum. The author ventured to hope that by that new view of the factors at work in determining the strength of cast iron, some further light would be thrown on the reasons for some of the great differences in mechanical strength of cast irons of apparently similar chemical analysis. The paramount influence of the rate of cooling of the metal in the mold was not lost sight of, but the author purposely avoided touching the many-sided problem involved in the consideration of the variations in strength due to varying thicknesses of a casting. The paper therefore sought to point out the differences in mechanical strength in castings of about $1^1/_4$ in. diameter, or 2 in. by 1 in. section, having approximately the same cooling ratio, perimeter of section ÷ area of section.

In the discussion which followed, T. H. Turner, of Birmingham, said that most of the workers who had tried adding nickel and chromium to cast iron had made practically no alteration to the cast iron itself. The advantage of nickel was obtained only when the silicon content was dropped, because silicon and nickel acted in the same direction, in that they produced graphite, but the nickel did not produce so much as silicon. Silicon tended to produce a coarse graphite and in some cases with extraordinarily successful heat treatment, it had given a graphite so fine that it could hardly be seen under the microscope. By various means one could alter the size of the graphite, and that was the fundamental thing in the strength of cast iron. (*The Engineer*, London, vol. 144, no. 3752, July 22, 1927, p. 94.)

A Smoke-Density Meter

A Discussion of the Desirability of Measuring Instruments in the Modern Boiler Room—Description of a Recently Developed Meter for the Measurement of Smoke Density, and an Explanation of the Manner in Which Such a Meter May Aid in the Abatement of Smoke and the Improvement of Furnace Efficiencies

By FRANK SAWFORD,[1] VANCOUVER, B. C.

THE matter of smoke abatement has been the subject of much discussion for many years, and great progress has been made in the design of boiler and other furnaces for the efficient burning of fuels with a minimum production of smoke.

The principles of proper combustion of fuels are now well known to engineers, and there is plenty of literature available on the subject. Furnace designs have become standardized for the purpose of burning fuels with better commercial efficiency and with the production of little or no smoke. It appears, therefore, that the problem of smoke abatement has been at least partially solved.

Every combustion engineer will admit, however, that while great progress has been made in the matter of smoke abatement, the problem is by no means satisfactorily solved; as evidenced by the fact that all large cities have in force ordinances and by-laws designed for regulating the emission of smoke from the stacks of boiler or other furnaces, and that even the modern plants with well-designed furnaces sometimes transgress the regulations.

It is the aim of plant operators, of course, whether trained engineers or not, to operate boiler plants under their charge with a maximum of efficiency; maximum efficiency being understood to mean the lowest possible consumption of fuel for raising the quantity of steam required.

To assist operators in maintaining, or at least approximating, such maximum efficiency, modern boiler plants are usually fitted with instruments to visualize or record the various factors which enter into the operation of the boilers.

The CO_2 indicator or recorder is perhaps the most valuable instrument for guiding the operator, as this is an index of combustion conditions, but the maintenance of a high CO_2 content of the flue gases does not necessarily mean high efficiency. The CO_2 indicator or recorder must be studied in conjunction with other factors.

The Bailey boiler meter also is a most valuable instrument, as this gives the rate at which steam is being generated and also the corresponding air flow required for that particular rating, as well as the temperature of the flue gases. These three factors, taken in conjunction with the CO_2 content of the flue gases, enable fairly good results to be obtained.

There is no guarantee, however, that even with the foregoing factors adjusted in proper relation, smokeless combustion is being obtained, otherwise it would not be necessary to fit boilers with soot blowers. As a matter of fact, a smokeless chimney does not necessarily mean efficient combustion. A fairly high CO_2 content of the flue gases may indicate efficient combustion, or in other words would indicate that a minimum of excess air is being admitted to the furnace; but it may also mean that insufficient air is being admitted, which will produce a smoky furnace, or the production of CO in addition to CO_2.

Jos. W. Hays in his popular book on "How to Build up Furnace Efficiency" states:

> Smoke is due to one of four causes, or to a combination of two or more of them, viz; (1) lack of air; (2) lack of mixture; (3) lack of temperature, and (4) lack of space.

It is apparent, therefore, that if an operator must run his boilers smokelessly and at the same time efficiently he must maintain a very nicely balanced condition at all times. This not only applies to the burning of bituminous coal, but also to fuel oil and wood refuse, and other fuels capable of producing smoke. In fact, fuel-oil smoke is far more harmful than any coal smoke from the point of view of waste of fuel. Wood refuse also, contrary to generally accepted opinion, will produce dense volumes of black smoke when burned under improper conditions.

As before stated, most cities have smoke regulations which provide penalties for the emission of black smoke for stated periods of time, and inspectors are usually appointed to watch chimneys and stacks for the purpose of checking the emission of smoke. In some sections of the country, however, no attempt has been made to solve the problem. Engineers are also rather inclined to consider that with the improvements in furnaces there are no smoking stacks with the modern plants. That this is not the case can easily be verified by the reports of smoke inspector in any city.

If a boiler plant is to be operated at its highest efficiency, it must of necessity be operated very close to the smoke danger line. If the smoke inspector is insistent, then the plant must be operated with a lower efficiency to be certain of not emitting smoke. As a consequence, a boiler operator leans toward the lower efficiency for the reason that the lowered efficiency of operation is not immediately apparent, whereas a smoky stack proclaims itself to the world in general and to the smoke inspector in particular.

The foregoing is not intended to convey the impression that a smoky stack is necessary for high efficiency; as a matter of fact, the reverse is true. A smoky stack is a proof of lowered efficiency, and should of course be avoided. It simply means a lack of air for combustion in the right place. An excess of air, assuming sufficient combustion space, will prevent smoke, but will lower the efficiency. As to how much excess air is permissible to prevent smoking depends entirely upon the type of stoker, or if hand fired, on the skill of the fireman, on the class of fuel, and many other factors, the most important being the uniformity of the fuel bed and the distribution of air to the furnace.

In some cases secondary combustion chambers are resorted to in order to consume the smoke after it is made in the furnace, but this is considered rather a clumsy method unless special conditions call for what might be styled the gas-producer method. That is, the furnace itself would in reality be a gas producer making some CO gas which would be burned to CO_2 in a secondary combustion chamber. In some wood-burning furnaces, where wood carries large amounts of moisture, this method is sometimes very successful.

It is asserted that perhaps the greatest factor in bringing about the improvements in the efficiency of operation of boiler furnaces in the last few years has been the development of suitable instruments for checking the various quantities and qualities entering into boiler operation, with the exception of the quality and quantity of smoke produced.

It is true that while improved operation brought about by the use of suitable instruments has rendered the smoke problem less acute, yet it is suggested that the lack of suitable instrumental means for definitely checking the quality and quantity of smoke in the same way, and with the same degree of accuracy that the other factors are checked, has caused the smoke problem to be somewhat ignored by engineers and operators.

There are instruments available of almost every conceivable kind for checking the various items which make for efficient operation, but the computation of the density of smoke produced by a boiler furnace has been entirely a matter of watching the smoke issue from the stack. The permissible density depends entirely on the personal element, the character of the sky as a background, and the relation to smoke emitted from other stacks, or the general character of the weather.

The Ringelmann smoke charts are, of course, of some assistance to the observer in determining the relative density or blackness

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of smoke. These charts are so well known that it is unnecessary to describe them here. The Ringelmann charts, however, while of some assistance, do not give positive indications of the density for the reasons before stated as to the character of the sky as a background, etc. It is also obviously impossible, or at least impracticable, for an observer to watch a stack continuously; and at night no observations whatever can be made.

The matter of emission of smoke from plants in cities where smoke regulations are in force places a plant operator in a very difficult position. He is held responsible for making the smoke, and in most cases does not know he is making it.

Where conditions are favorable, mirrors are placed in such a position that the operator can see the reflection of the top of the stack from the boiler room. This is a help whenever it is possible.

Other devices have also been tried, such as placing an electric lamp in front of an aperture in the side of the boiler uptake, and placing an inclined mirror in front of a second aperture at the other side of the uptake in line with the first aperture. If the reflection of the lamp is visible in the mirror, no smoke is being made.

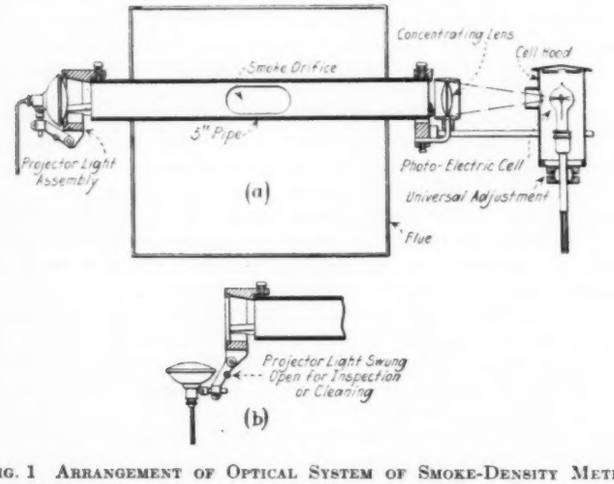

FIG. 1 ARRANGEMENT OF OPTICAL SYSTEM OF SMOKE-DENSITY METER

This device obviously is very crude, and is at best only a makeshift and unsatisfactory.

In making boiler tests where smoke determinations have to be made, and also to assist smoke inspectors, it is probable that there has been no better method evolved up to the present time than the Ringelmann charts previously referred to.

It is suggested that there is a great need of some practical instrument or method of measuring or computing the density of smoke without the necessity of personal observations of the stack.

It is believed that an instrument for indicating or recording the density of smoke in practical terms, to be used alongside the CO_2 instrument in every boiler room, is almost as necessary as the CO_2 instrument itself.

A practical smoke-density meter used in conjunction with a CO_2 indicator would enable a boiler operator to run his plant at the highest possible efficiency, and at the same time comply with the smoke regulations.

The author gave considerable study to the problem of computing the exact density and duration of smoke from stacks over twenty-five years ago, the idea being to devise some means to indicate to the operator in the boiler room, and also if possible to record, the density and duration of smoke. At that time he was in charge of a battery of six 600-hp. boilers with inclined-grate stokers burning bituminous coal, and much trouble was experienced with smoke, repeated warnings and fines being imposed at the instance of the smoke inspector.

A device was conceived and experimented with whereby a beam of light from an electric lamp was projected across the smoke flue, and was arranged to shine on a selenium cell which was connected electrically to an electrical instrument calibrated for use as a smoke meter. After a considerable amount of experimenting, however, this device was abandoned for the reason that the electrical currents handled were too feeble, and the selenium cell was too erratic and deteriorated too rapidly.

With the recent development of radio apparatus for amplifying weak currents, and in conjunction therewith the development of a practical and satisfactory light-sensitive cell, or, as it is called, a photo-electric cell, the scheme outlined above has been revived, and after some intensive experiment and study with apparatus now available a practical smoke-density meter has been developed which is suitable for indicating and recording, either separately or in combination, the actual density of smoke.

It should be mentioned here that a photo-electric cell in combination with a radio amplifying tube was suggested early in 1926 for use as a smoke detector, and was described in an article by S. H. Reynolds, published in *The Electric Journal*, March, 1926.

This scheme suggested the use of the combination of a photo-electric cell, amplifying tube, and a sensitive relay to ring an alarm bell whenever smoke was being produced. So far as is known, however, this device has not come into practical use.

The purpose of this paper is to describe the development of a smoke-density meter which indicates and records the actual density of smoke in practical units, for continuous operation as a boiler-room instrument.

This instrument makes use of the photo-electric cell and amplifying vacuum tube, but instead of a relay, use is made of an indicating and recording instrument to measure actual smoke density.

Briefly, the instrument consists of two principal parts. One part, which may be termed the instrument proper, consisting of an indicator or recorder or both, is mounted on or near the boiler front, or any suitable location convenient to the operator. Within the instrument is contained the current-amplifying apparatus, forming a complete self-contained unit. The second part, which may be termed the optical system, is placed in the smoke flue or chimney at any convenient suitable point, preferably at a point where the temperature of the flue gases is not excessive, although the usual flue temperatures from boiler outlets are not detrimental.

As the optical system is really the basis of the device, it will perhaps be in order to describe this first. For a permanent installation, a length of ordinary 3-in. iron pipe is inserted through the flue or stack at any convenient point. This is shown at (*a*) in Fig. 1. The pipe extends about six inches outside each side of the flue. In the center of the pipe is cut an elongated opening for a smoke orifice, through both walls of the pipe, and this orifice is placed parallel to the stream flow of the flue gases. The area of this orifice bears a relation to the area of the flue and velocity of the gases. At one end of this smoke-orifice pipe is mounted, by means of a cast-iron bracket, a lamp giving a parallel beam of light, similar to an ordinary automobile spotlight. The lamp is mounted on a spring-hinged adjustable arm to enable a correct adjustment of the beam, as well as supplying a means for focusing. Normally the lamp is pressed against a rubber cushion by the spring pressure, but can be swung clear for cleaning or inspection without disturbing the adjustments, as shown at (*b*) Fig. 1. The lamp itself is an ordinary 6-volt, 21-candle power, concentrated-filament lamp. At the other end of the smoke pipe is mounted the light-sensitive cell, together with a concentrating lens, each with universal adjustments; the whole being assembled on a cast-iron bracket clamped to the smoke pipe in a manner similar to the lamp at the other end.

Both cast-iron mounting brackets are arranged with air spaces to enable a stream of air to enter the pipe at both ends under the suction of the flue. This air has the dual effect of keeping the mountings cool, and also preventing the deposition of soot in the orifice. The stream of air passing into each end of the pipe also has the effect of inducing a definite flow of a portion of the flue gases and smoke, if any, through the orifice. Any smoke flowing through the orifice, of course, acts as a screen for the beam of light projected through the smoke pipe, and the intensity of the light reaching the photo-electric cell is proportional to the density of the smoke flowing through the orifice.

The smoke pipe being rigid also keeps the light projector and photo-electric cell in absolute alignment, entirely independent of any movement in the flue casing caused by expansion and contraction due to temperature variations. Early experiments in which the lamp and photo-electric cell assemblies were mounted on the sides of the flue without the use of a smoke pipe proved that it was extremely difficult to maintain correct alignment, and also that the light intensity affecting the photo-electric cell bore no relation

to the smoke density, being dependent on the distance across the flue and the velocity of the gases.

The photo-electric cell, while very simple, is rather an interesting piece of apparatus. It is this device which has rendered possible the transmission of photographs by wire, facsimile writing and other matter, and television. It is made in several forms, but the type chosen for this smoke-density meter is in the form and size of an ordinary 60-watt electric lamp, and has a standard Edison screw base for use in a standard electric-light socket.

The principle and construction of the photo-electric cell is fairly well known to the electrical world, but a brief description here may not be out of place. The action of the cell is based on the fact that the metal potassium, together with some other like metals, is sensitive to light under suitable conditions. In this case potassium is deposited on the inside of the glass bulb, which is previously silvered, a portion of the bulb being left clear, or at least a circular spot about $1^1/_2$ in. in diameter is left clear for a "window" for passing light through to the light-sensitive surface. The potassium coating is in contact with a conductor connected with one terminal of the screw base. The potassium forms the cathode of the cell. The anode is a loop of wire mounted in the center of the bulb and connected with the other terminal of the screw base. The bulb is exhausted of air, and neon gas is substituted at a pressure of 3 millimeters of mercury. When the cell is dark, no electrical conducting path exists between anode and cathode. When light falls on the potassium surface, electrons are given off, which in turn excite electrons in the gas-filled space, causing a slight conducting medium between the anode and cathode. The emission of the electron stream is similar to that taking place in the well-known radio vacuum tubes or valves. In the case of the cell, however, the intensity of the electronic stream, and consequently the electrical conductivity from anode to cathode, is nearly proportional to the intensity of the light when proper adjustments are made of the outside electrical circuits to which the cell is connected.

A diagram of the electrical circuits is shown in Fig. 2. It will be noted that the photo-electric cell forms a bridge across the plate and grid of an ordinary amplifying tube. The cell when thus connected functions as a variable resistance, its resistance varying with the intensity of light thrown on to the sensitive surface.

The amplifying tube operates in a manner similar to that of the radio tube with the exception that the current flow from the filament to plate of the tube in the indicator is retarded by impressing a sufficiently high negative potential on the grid to reduce the current flow from filament to grid almost to zero.

When light is thrown on the sensitive surface of the cell, the electron stream emitted by the potassium surface forms a current-conducting path of extremely high resistance between the plate and grid of the amplifying tube, allowing a positive potential from the plate to be impressed on the grid, and permitting a current to flow from filament to plate proportional to the reduction of resistance of the photo-electric cell, whose resistance is governed by the light intensity on the sensitive surface of the photo-electric cell. The light intensity, which is a measure of the smoke density, is measured by means of a standard milliammeter of the D'Arsonval moving-coil type connected in the filament-to-plate circuit, this milliammeter having a suitably calibrated scale for the measurement of smoke density.

The amplifying tube, together with the necessary rheostats for adjustment of the electrical conditions, also the current-regulating or rectifying apparatus, is contained within a steel or cast-iron box, together with the indicating or recording meter, forming a self-contained and complete unit for wall mounting.

It is necessary, of course, that the amplifying tube and photo-electric cell circuits be supplied with direct current at a suitable voltage. The amplifying circuit is supplied with direct current at a total potential of from 120 to 130 volts, approximately 25 per cent of this voltage being impressed on the grid of the tube and the balance on the plate, the tap which divides this voltage being connected to the filament. This direct current may be furnished from supply lines if available, but if only alternating current is available the supply may be furnished by means of rectifiers with filter circuits for choking back and bypassing any alternating current which may pass through the rectifier, similar to the B-battery eliminators used for radio service. The current may also be obtained by means of a small motor-generator set, or from batteries. The use of batteries, however, while ideal as a source of current supply, is objectionable on account of the large space required which makes it difficult to incorporate them in the meter box, and also on account of the maintenance required.

The so-called B-battery eliminator, which has become so popular in radio work, is quite suitable, and a modification of this device is being used with some degree of success. The B eliminator, however, is not quite so efficient as a battery, on account of the possibility of a slight alternating-current ripple being superimposed on the direct current applied to the photo-electric cell. This ripple, if at all pronounced, would damage the cell by causing it to glow like a neon tube or lamp. This glowing can also be caused by a too high voltage of direct current, and must be avoided as it destroys the sensitive surface of the potassium coating.

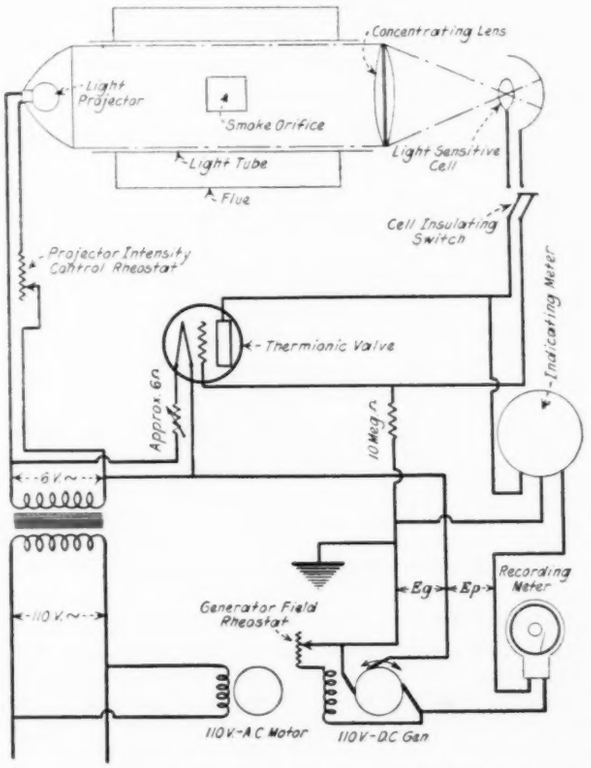

FIG. 2 SCHEMATIC ARRANGEMENT OF SMOKE-DENSITY METER

The method preferred therefore at present, where no suitable direct-current supply is available, is the use of a small motor-generator set; the motor being wound for the alternating-current supply voltage, and the generator designed to supply about 135 volts direct-current with a third brush to supply the grid potential. The field of the generator is regulated by a small rheostat to allow adjustment of the full potential, while the grid voltage is regulated by adjustment of the third brush. This third brush is mounted on a separate stud for adjustment independently of the main brushes.

The entire motor-generator set is very small and compact, the total output of direct current required being only 10 milliamperes for the amplifying tube, photo cell, and meter circuits. The set is fitted with ball bearings, and is arranged for continuous service without attention.

The current supply for the filament of the amplifying tube and for the projector light on the smoke-orifice pipe may, of course, be alternating current, and this is supplied by means of a small transformer giving a secondary voltage of 6 to 8 volts.

Research is being carried on, however, with the B eliminator, as this is to be preferred to the motor-generator set, provided a pure direct current can be depended on without any possibility of superimposed alternating-current ripples. Results so far are very encouraging, and it is hoped that this method will finally supersede the motor generator, which will reduce the manufacturing costs of the instrument and make it more compact.

A general arrangement of the motor-generator type of instrument is shown in Fig. 3. This shows the whole of the apparatus mounted on a substantial steel-plate panel. The step-down transformer is compactly mounted between the motor and generator. To the right of the motor generator is arranged the regulating rheostats for the generator field, the filament of the amplifying tube, and the projector lamp. There is also a double-pole switch for cutting off the photo cell. All of this equipment is mounted on a bakelite panel supported from the steel panel by four brass posts. On the top of the posts is mounted a bakelite panel carrying the amplifying tube and socket, together with the grid resistors. At

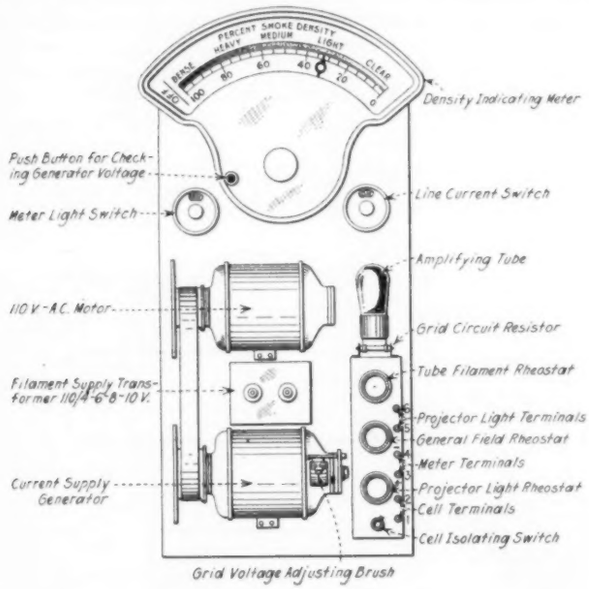

FIG. 3 GENERAL ARRANGEMENT OF CURRENT-SUPPLY EQUIPMENT FOR SMOKE-DENSITY METER

the top of the steel panel is mounted a large meter of the illuminated-dial type. This meter is a milliammeter with a full-scale reading of 10 milliamperes, and is also fitted with high-resistance coils and a push-button switch to enable voltage readings to be taken for checking the generator voltage. Normally, however, the meter reads milliamperes, the scale being calibrated in percentage smoke density.

An ordinary double-pole snap switch is mounted on each side of the meter. The right-hand switch controls the current supply to the entire apparatus, and the left-hand switch controls the lights behind the illuminated dial.

It will be noted that, reading from right to left, the scale is marked 0–100 per cent density. When the current supply is switched off, the pointer rests at the "off" position shown at the extreme left.

With the current supply switched on the motor-generator starts up, and the direct-current voltage is adjusted by means of the field rheostat to 130. A volt scale marked in small red figures, superimposed on the density scale, facilitates this reading. With the photo-electric cell and the projector light switched off the third brush of the generator is then adjusted until the pointer reads 100 per cent density. The photo cell is then switched in, the pointer remaining stationary except for a slight flicker, after which the projector-light rheostat is adjusted until the pointer reads zero density with no smoke passing. The meter will then register correct smoke density. Should the direct-current voltage be adjusted to a higher or lower value than 130 volts, within limits, no appreciable error will be introduced provided the intensity of the projector lamp is adjusted accordingly.

The instrument therefore is self-checking; it is only necessary that the direct-current voltage be adjusted to approximately 130 volts (preferably lower than higher), and then to adjust the projector light until the meter reads zero density, provided it is known that no smoke is being produced.

It is very important that the direct-current voltage be kept well below the glowing point of the photo-electric cell. A glow discharge at the cell will be immediately apparent on the meter by violent fluctuation of the pointer. In some cases it may be necessary to keep the direct current down to 110 volts and to increase the light intensity accordingly. As the density reading is proportional to the sum of the light intensity and the voltage impressed across the cell, the density readings are not appreciably affected.

It is also very important that there be no leakage between the leads connecting the photo-electric cell to the current-supply apparatus, as such leakage would render the meter readings of no value. Any leakage which might exist, however, can be detected on the meter by cutting off the projector light and the cell, when the reading should be 100 per cent density. If not, the reading must be adjusted to that value by adjustment of the brush in the case of the generator, and by adjustment of the grid bias voltage in the case of a battery or potentiometer circuit.

With this adjustment correct no appreciable change in the reading should be apparent when the photo-electric cell is switched in (provided the cell hood is in place and no light is reaching the cell) except a momentary flick of the pointer due to the capacity of the leads to the cell.

The deflection of the pointer, therefore, with all above adjustments made is entirely due to the intensity of the light reaching the cell, provided no leakage exists. As an indication of the extreme sensitivity of the apparatus, and the effect of leakage, it may be stated that if the fingers are placed across the cell terminals, the meter pointer will be thrown violently across the scale. The greatest danger is leakage across the surfaces of the cell socket and switch, due to moisture. To prevent this

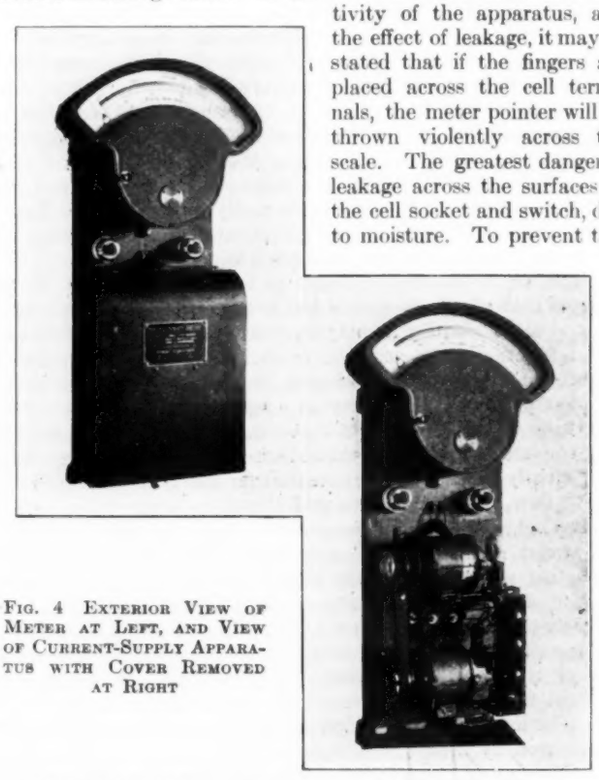

FIG. 4 EXTERIOR VIEW OF METER AT LEFT, AND VIEW OF CURRENT-SUPPLY APPARATUS WITH COVER REMOVED AT RIGHT

the socket and switch are entirely covered with baked-on insulating varnish. The screw base of the cell also is treated in the same way.

It will be noted that the readings are counter-clockwise, that is, zero smoke density is at the extreme right. This reading, however, is actually the full-scale reading in milliamperes. It is thus apparent that for an operator to have his instruments indicating or recording, he must have them in proper working order. Switching out the light and cell will show only 100 per cent density, while if the whole apparatus is switched off the pointer will move to the "off" position. The deflection from the "off" position to 100 per cent density is equivalent to about half a milliampere.

This method forms not only a check on the instrument but it is also a check on the operator, as he cannot make false smoke records. He can of course increase the intensity of the light to show better smoke conditions than actually exist, but this will show up immediately during a period of no smoke when the pointer moves beyond the zero position.

Fig. 4 shows the meter both with and without the cover in place.

As regards the accuracy of the meter scale, readings shown in Figs. 5 and 6 show the relation between the actual intensity and meter reading. Fig. 5 shows the characteristics of the photo-electric cell. It will be noted that the saturation point occurs at about 24 foot-candles and 14 milliamperes. For the purpose of this density meter, only that portion of the curve is made use of lying between 18 foot-candles and 10 milliamperes.

Fig. 6 shows the actual curve of smoke density, or really, light intensity, in foot-candles against the actual meter reading when the scale is graduated into uniform divisions. This curve also shows the Ringelmann-chart numbers corresponding to the actual density. This curve was checked by constructing screens made to exact relative dimensions by means of black-paper strips to the corresponding Ringelmann charts. These screens were placed behind the concentrating lens on the smoke pipe, and the actual meter readings thus obtained are shown on the curve. Fig. 7 gives the percentage density of the Ringelmann charts calculated from the standard dimensions.

A careful inspection of the foregoing curves will show how closely the meter readings correspond to actual smoke density. Smoke density under these conditions can therefore be interpreted to mean percentage blackness, or opacity to transmitted light.

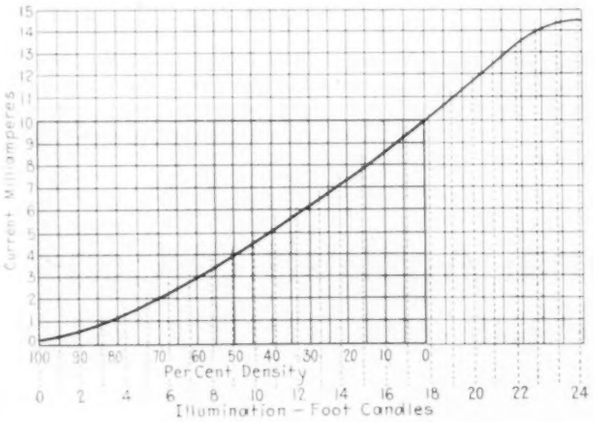

FIG. 5 PER CENT DENSITY-CURRENT CURVE

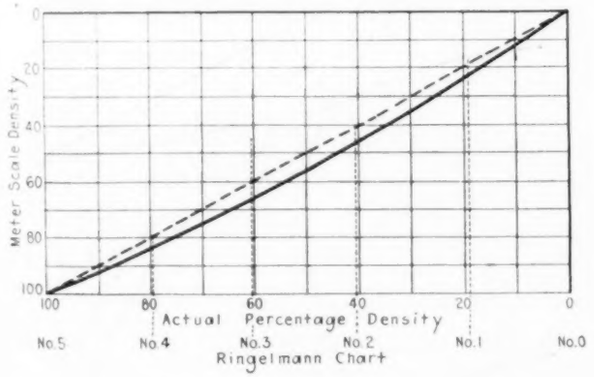

FIG. 6 COMPARISON CURVE OF DENSITY METER SCALE WITH RINGELMANN CHART AND ACTUAL DENSITY

The illuminated scale has above it a band graduated from black at 100 per cent and fading out to clear at zero density (see Figs. 3 and 4). Above this band are also marked the words "clear," "light," "medium," "heavy," "dense." This marking is, of course, not essential, but is a guide to the observer as to what percentages readings denote. Actually 20, 40, 60, and 80 per cent readings correspond approximately to Ringelmann charts Nos. 1, 2, 3, and 4, respectively.

As previously stated, the whole current supply and amplifying apparatus is enclosed in a steel or cast-iron cabinet to shield it from outside inductive or radio disturbances. The wiring to the smoke-orifice pipe also must be enclosed in conduit for the same purpose.

Referring again to the photo-electric cell, it should be stated that while the characteristic curve of the potassium-type cell is uniform for all cells, the sensitivities of different cells vary considerably, due to a slight uncertainty in manufacture. This variation is not of great consequence in the case of the smoke meter, however, as correct adjustments can be made at any time after installation by regulating the light intensity. This adjustment is of course also necessary to allow for the aging or reduction in brilliancy of the projector light. The photo-electric cell, however, does not change appreciably, unless it is allowed to glow though the use of excessive voltage.

One peculiar characteristic of the cell should be noted for the

Card No.0	All White		0% Dense
Card No.1	Black Lines 1 Millimeter Thick. White Squares 9 Millimeters Square. 19% Black – 89% White.		19.00% Dense
Card No.2	Black Lines 2.3 Millimeters Thick. White Squares 7.7 Millimeters Square. 40.71% Black – 59.29% White.		40.71% Dense
Card No.3	Black Lines 3.7 Millimeters Thick. White Squares 6.3 Millimeters Square 60.31% Black – 39.69% White.		60.31% Dense
Card No.4	Black Lines 5.5 Millimeters Thick. White Squares 4.5 Millimeters Square. 79.75% Black – 20.25% White.		79.75% Dense
Card No.5	All Black		100% Dense

FIG. 7 SPECIFICATION FOR RINGELMANN SMOKE-DENSITY CHARTS

guidance of users. When first switched in circuit the sensitivity and, consequently, the current flow, is much higher than normal. This throws the needle beyond the zero point of the scale, but in a few seconds it falls back to normal, after which the cell remains constant. This change occurs if the cell is switched off for only a short time, and repeats at every switching. This characteristic is not considered detrimental, and does not affect the accuracy of the meter readings in any way, but it should be understood to prevent confusion in operation. The life is indefinite, and may be said to be practically permanent. The only renewals are the projector-lamp bulb and the amplifying tube, and these have an average life of about 2000 hours, unless conditions require full voltage, in which case the life would be about 1000 hours.

Beyond the photo-electric cell there is no special apparatus required for the entire equipment. The amplifying tube is a standard UX–171 tube. The projector lamp is of the standard 6-volt, 21-candle power, automobile type. The rheostats are of the ordinary radio type. The motor-generator set is of a standard type which has a good voltage regulation, and the meter is any good-type, moving-coil volt-milliammeter. The recorder also is of a standard type having a full-scale reading of 10 milliamperes.

An instrument having a combined indicating volt-milliammeter and a milliampere recorder in the same case with the current supply and adjusting apparatus is in the process of development, and will be available for use in the near future.

The indicating meter has a round dial with a scale of 300 deg., and is marked in per cent density, while the recorder is of the strip-chart style with a pen recorder.

A portable testing density meter also is being developed in which a small indicating meter, together with the current-supply and regulating apparatus is obtained in a wood case for use on a lamp socket supply. The smoke-orifice pipe for the portable type consists of several 2-ft. lengths of 2-in. seamless tubing threaded to screw together with flush joints to make up to the length desired for any size of flue or stack.

The projector light and photo-electric cell mountings are clamped to the ends of the smoke-orifice pipe, the whole being arranged for dismounting and packing in a carrying case.

It is hoped that the smoke-density meter will not only prove a help in the work of eliminating the smoke nuisance in our cities, but will also provide a means for improved efficiency in the oper-

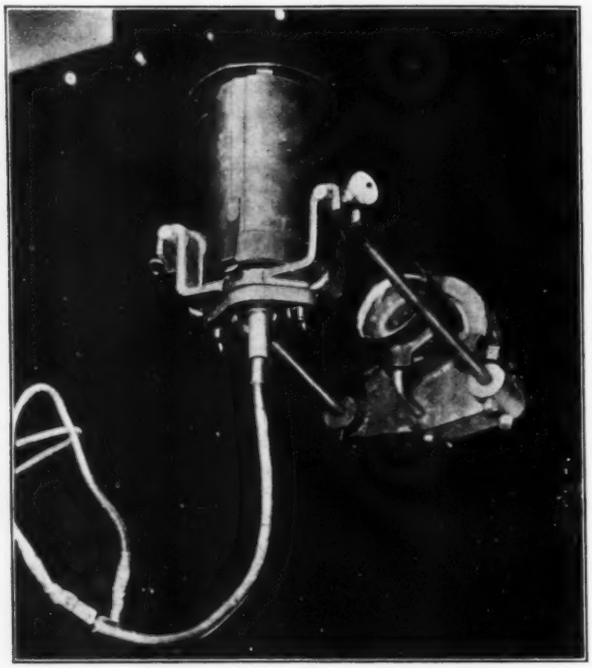

FIG. 8 OPTICAL SYSTEM INSTALLED IN HORIZONTAL STEEL-PLATE FLUE—PHOTO-ELECTRIC-CELL END

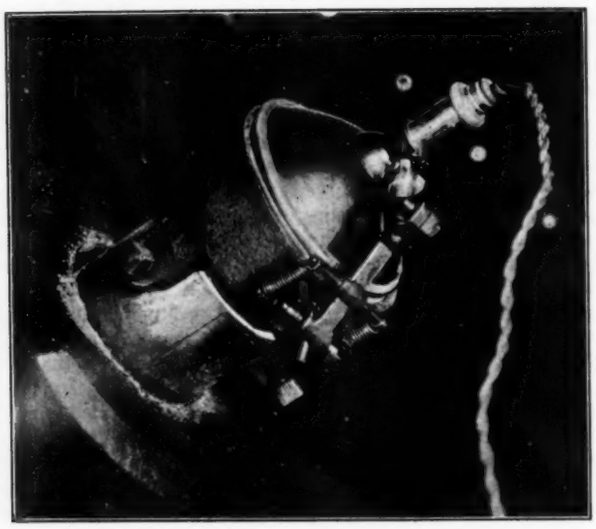

FIG. 9 OPTICAL SYSTEM INSTALLED IN HORIZONTAL STEEL-PLATE FLUE—PROJECTOR-LIGHT END

ation of boilers and furnaces. It is believed that the meter now completes the line of instruments necessary in the boiler room to indicate and record all the various factors of operation which are required to be known if fuel is to be burned in a manner productive of economy.

Application of Dimensional Analysis to Centrifugal Fans

BY ERNEST M. FERNALD,[1] EASTON, PA.

A COMMON notion regarding centrifugal fans is stated in a well-known handbook thus:

> Where a given fan is operating with a given restriction on its inlet or outlet, the volume delivered will vary directly with the r.p.m. (N), the various pressures as N^2, and the air horsepower as N^3. The mechanical efficiency will remain the same, therefore, the b.hp. will also vary as N^3. The volume delivered by symmetrical [geometrically similar] fans will vary as D^3 for any given peripheral speed of the wheel and resistance or static pressure. Under these conditions the mechanical efficiency remains constant, since the area of the friction surfaces varies directly with the change in volume. The horsepower will, therefore, also vary as D^3.

A little thought, however, shows that the statement regarding a given fan cannot be exactly true. Consider a fan discharging into a long, smooth pipe. According to the statement quoted, the static pressure at the fan outlet would vary as the square of the velocity (since it varies as N^2; and quantity Q, or velocity V, varies as N). But the pressure at the fan outlet is also the pressure at the beginning of the pipe, and is the pressure necessary to force the air through the pipe. If the resistance of the pipe varies as the square of the velocity, well and good, and the quoted statement is at least in part possible. But if the pipe is smooth and free from obstruction, the resistance may well vary as some power less than the square. Hence, if the speed of the fan were doubled, and the fan should then maintain at the entrance of the pipe a pressure equal to four times the original pressure, more than twice the original amount of air would necessarily be forced through the pipe. That is, if the pressure P varied as N^2, Q could not vary as N, but would have to vary as N^{1+}. And even though the piping system were such that Q varied as N, and P as N^2—air horsepower hence varying as N^3—the efficiency would not remain constant unless the losses varied as N^2 or V^2.

There are two kinds of losses in a fan, eddy losses and frictional losses. Eddy losses vary as the square of the velocity, but frictional losses vary as a power less than the square, the coefficient of friction decreasing as velocity increases. Hence frictional loss would be relatively less at high speeds, and the fan correspondingly more efficient. This is confirmed by experiment. Also, the coefficient of friction decreases with increase in size of air passage.

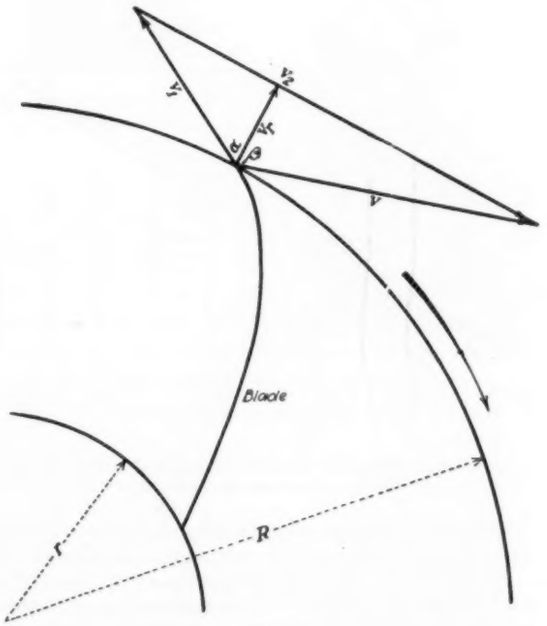

FIG. 1

Hence, a correct statement regarding geometrically similar fans

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would be that the larger sizes are the more efficient. The common notion given in the quotation at the beginning of the paper is therefore inaccurate because the relation between pressure and quantity when a fan is discharging into a fixed piping system is determined by the piping system, and the relation is not always P varies as Q^2. It is inaccurate also because the coefficient of fluid friction is assumed to be constant, whereas it is well known to be variable.

Dimensional analysis, however, gives a true account of what may be expected of a given fan, and of geometrically similar fans.

Let
D = size of fan
N = speed
Q = quantity per unit time
w = density of air or gas
z = viscosity of air or gas
P = static pressure
BHP = input horsepower
AHP = air horsepower.

When D, N, Q, w, and z are fixed, P and BHP are determined. Therefore,

$$f_1(P,D,N,Q,w,z) = 0 \quad [1]$$

$$f_2(BHP,D,N,Q,w,z) = 0 \quad [2]$$

As the units of all these quantities are completely expressible in terms of the three units of length, mass, and time, Equations [1] and [2] can each be replaced by a function of three dimensionless products. Thus[2]

$$F_1\left(\frac{P}{wN^2D^2}, \frac{Q}{ND^3}, \frac{ND^2w}{z}\right) = 0 \quad [3]$$

$$F_2\left(\frac{BHP}{wN^3D^5}, \frac{Q}{ND^3}, \frac{ND^2w}{z}\right) = 0 \quad [4]$$

whence
$$P = wN^2D^2\Phi_1(Q/ND^3, ND^2w/z) \quad [5]$$

$$BHP = wN^3D^5\,\Phi_2(Q/ND^3, ND^2w/z) \quad [6]$$

The total pressure P'

$= P + wV^2/2g$ (in which V = velocity through the outlet)
$= P + c_1wQ^2/D^4$ (in which c_1 is a constant)
$= wN^2D^2\,\Phi_1(Q/ND^3, ND^2w/z) + c_1wN^2D^2(Q/ND^3)^2$

$$= wN^2D^2\,\Phi_3(Q/ND^3, ND^2w/z) \quad [7]$$

$AHP = c_2P'Q$ (in which c_2 is a constant)
$= c_2wN^2D^2Q\,\Phi_3(Q/ND^3, ND^2w/z)$
$= c_2(wN^3D^5)\,(Q/ND^3)\,\Phi_3(Q/ND^3, ND^2w/z)$

$$= wN^3D^5\,\Phi_4(Q/ND^3, ND^2w/z) \quad [8]$$

Efficiency $= e = AHP/BHP$

$$= \Phi_5(Q/ND^3, ND^2w/z) \quad [9]$$

Pressure and power depend partly, and efficiency wholly, on some function of the variables Q/ND^3 and ND^2w/z.

These two variables have important physical significance. In Fig. 1, which shows a velocity diagram for the air leaving the wheel,

v_1 = velocity relative to the blade
v_2 = tip speed
v = absolute velocity
v_r = radial component of absolute velocity
α = angle of blade with radius
β = angle of v with radius.

Now

$$v_2 = \pi ND \quad [10]$$

in which D is the diameter of the wheel, and may serve also to denote the size of the fan in Equations [1] through [8].

[2] For the method of obtaining the dimensionless products see Buckingham—Model Experiments and the Form of Empirical Equations. Trans. A.S.M.E. (1915), vol. 37, p. 263.
Bridgman, Dimensional Analysis. Yale Univ. Press, 1922.

Q = $v_r \times$ area perpendicular to the radius $= c_2v_rD^2$

whence

$$v_r = c'_2\,Q/D^2 \quad [11]$$

in which c_2 and c'_2 are constants.

$$v_2 = v_r \tan\alpha + v_r \tan\beta = \pi ND \quad [12]$$

$$\tan\beta = \frac{\pi ND}{v_r} - \tan\alpha = \frac{\pi ND}{c'_2Q/D^2} - \tan\alpha = \frac{c_3}{Q/ND^3} - \tan\alpha \quad [13]$$

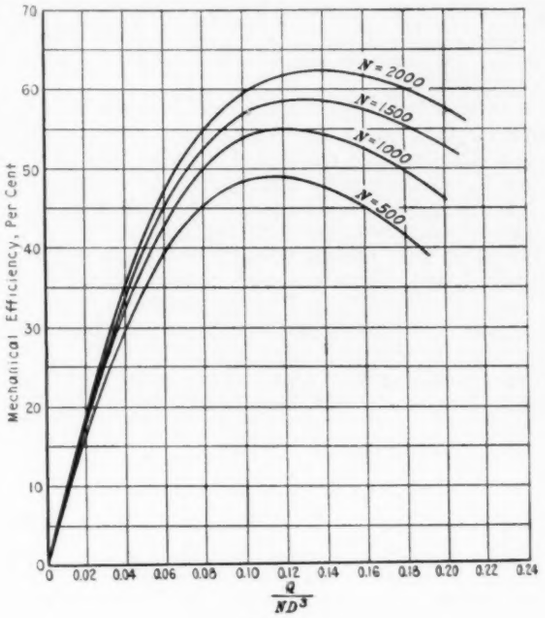

FIG. 2

The angle β at which the air leaves the wheel therefore depends on the blade angle α and on Q/ND^3. A similar expression obtains for the tangent of the angle at which the air enters the wheel. As these two angles determine the gross eddy loss in the wheel and in the casing, it is clear why pressure, power, and efficiency should depend on Q/ND^3. ND^2w/z may be written $(ND \times D)/y$, in which $y = z/w$ = kinematic viscosity. For a given value of Q/ND^3, ND is proportional to Q/D^2 and hence to the velocity of air through the fan—both average velocity and velocity in each particular part. ND^2w/z is therefore equivalent to Reynold's number, VL/y, which determines the coefficient of fluid friction. ND^2w/z appears in Equations [3] through [9] because friction is a factor in fan performance.

The considerable influence of variation in coefficient of friction is shown by Fig. 2, which applies to a cast-shell forge blower having a 7-in. double inlet and a 4.95-in. outlet. The wheel is 17 in. in diameter and has 10 straight radial blades. The power absorbed by the bearings was determined and subtracted from the gross input, so that the power charged against the fan is only that necessary to turn the wheel. The increase in efficiency with speed shown in Fig. 2 is to be expected, because ND^2w/z increases with speed, and the larger the Reynold's number, the less is the coefficient of friction. For the same reason, the larger sizes of similar fans should be the more efficient, which is also known to be true. The efficiency of a fan when handling hot gases should be lower than when handling cold gases, for as temperature increases density decreases and viscosity increases, making $ND^2\,w/z$ smaller.

Dimensional analysis therefore affords satisfactory explanation of the general characteristics of geometrically similar centrifugal fans, by showing that the ratios Pressure/wN^2D^2, Power/wN^3D^5, and efficiency, are all functions of the two variables Q/ND^3 and ND^2w/z, whose physical significance is easily understood. Q/ND^3 determines the gross eddy loss and ND^2w/z determines the frictional loss. For a given value of Q/ND^3, efficiency increases with increase in ND^2w/z. The efficiency of a given fan is therefore greater at high speeds, the efficiency of similar fans greater for the larger sizes, and efficiency is less when a fan is handling hot gases.

Beet-Sugar Manufacture

Early History of Beet-Sugar Industry—Sugar Yields per Ton of Beets—Processes in Common Use—Steps in Manufacture—By-Products—Recovery of Sugar from Molasses—Beet-Sugar Factory Equipment, and Facilities for Maintenance

By W. Y. CANNON,[1] CHINOOK, MONT.

THE word "sugar" has been traced back to the ancient Persian "shaker." However, the old Sanskrit from India is "carkara," which means gravel, and undoubtedly refers to the early crystallized sugar.

Sugar appears to have been known and in use in India for many hundreds of years before the Christian era. Among the ancient Chinese writings we find mention of sugar as early as the eighth century B.C. In the seventh century B.C., according to the Bible, Jeremiah wrote: "To what purpose cometh there to me incense from the Sheba and sweet cane from far country?"

It is evident from ancient writings that sugar and cane were highly prized, and tribute was often paid in sugar. While sugar came into use medicinally and among the wealthy very early, it has only been in the last century that its price has been sufficiently reasonable for the average family to use it.

The manufacture of beet sugar is of comparatively recent origin. During the Napoleonic wars, large bounties were paid by France for establishing beet-sugar factories, so that the spread of the industry in France was rapid during that period.

Early History of Industry

Andrew S. Marggraf, a member of the Berlin Academy of Science, was the first to crystallize sugar from sugar beets. It remained for a pupil of Marggraf, Karl Franz Achard, son of a French refugee in Prussia, to work out the process for commercial production, and the first factory was built about 1800 in Germany.

The first factory built in the United States was erected at Northampton, Mass., in 1838, but was not a commercial success. The Mormon pioneers shipped machinery from France in 1852. This was shipped by boat to Fort Leavenworth, Kan., and then hauled by ox team to Utah. Fifty-two teams required four months to haul the machinery. This venture also was a failure.

Numerous other ventures throughout the United States were made, but after many experiments and failures, E. H. Dyer established a factory at Alvarado, Cal., in 1879, which he was able to put on a paying basis. From that time the industry spread slowly until about 1900, when considerable impetus was given to the business on account of favorable tariff laws.

The 1926 production of beet sugar in the United States was 897,000 tons, which is less than 20 per cent of the consumption in this country.

The growing of sugar beets is spread over the northern part of the United States, the greatest production being in the irrigated sections of Colorado, Utah, Idaho, Nebraska, Wyoming, and Montana. In California, Michigan, Ohio, Minnesota, Wisconsin, Washington, and several of the middle-western states they are grown without irrigation. The growing requires intensive hand work, as the beets are thinned in the spring and topped in the fall by hand labor. While various machines have been developed for this work, they have been unsuccessful so far. Very beneficial results come from beet culture as a part of rotation in farming, greater yields coming to other crops following beets. It has been very evident in all successful beet-growing sections that land values increase and farming methods are better.

Sugar Yields per Ton of Beets

Sugar beets contain from 280 lb. to 400 lb. of sugar per ton. The highest sugar content is found in California where the growing season is long and the tonnage per acre generally light.

In Michigan, Ohio, and irrigated sections of the West, the sugar content in unfavorable years may be as low as 14 per cent, but the average is from 15 per cent to 17 per cent, or 300 lb. to 340 lb. of sugar per ton of beets. In a "straight house" from 75 per cent to 80 per cent of this sugar in the beet is sacked as granulated sugar. By a straight house is meant one in which the sugar in the molasses is not recovered. The losses are made up of shrinkage of the beets in storage—between receiving and slicing—loss in beet pulp, loss in lime-mud cake, and loss in molasses. The molasses loss is the greatest, followed next by the loss in shrinkage.

Processes

There are several processes whereby the sugar in the molasses can be recovered, but all are not commercially profitable. The Steffen process is the most generally used. It is an auxiliary process and is used in about 40 per cent of the plants in this country. In plants using this process, approximately 90 per cent of the sugar in the beet is put into the bags as granulated sugar. The cost of the sugar in these plants is generally higher, but greater profit is made when sugar brings a good price.

An important item governing the extraction is the purity of the juices. The presence of impurities prevents the crystallization of some of the sugar. This goes to form molasses. Of the soluble solids present in beets, 80 to 88 per cent will be sugar. In sugar parlance, purity is the percentage of sugar as compared with the total soluble solids. One of the aims of the process is to eliminate as many impurities as possible, thus cutting down the molasses-forming salts.

The factories in this country average from 500 to 3000 tons of beets per 24 hours. The most popular sizes at the present time are from 1000 tons to 1500 tons capacity. This depends on the prospective supply of beets and the ideas of various operating heads.

Steps in Manufacture

The manufacture of sugar divides itself into the following subdivisions:

1 Receiving and storing the beets
2 Washing, or cleansing, and slicing the beets
3 Diffusion of the sugar, by water, from the beets
4 Purification of the juice
5 Evaporation of the water to form a juice
6 Formation of crystals
7 Separating the crystals from residue syrups
8 Drying, sacking, and storing the sugar
9 Working the after-products
10 By-products: beet pulp, molasses
11 Machinery and equipment.

Beets are received by the sugar companies at designated railroad sidings or at the factory. At the more modern factories belt conveyors handle the beets from the farmer's wagon into the railroad car. The beets are screened and the excess dirt is returned to the farmer. A portion of each load is thoroughly cleaned and the tare taken to arrive at the net weight of the load.

Storage. The beets are transported to the factory by rail and are either dumped from railroad highline direct into the sheds, or into car hoppers with conveyor belts to distribute the beets into the sheds, which are about 500 ft. long and are not roofed over. Storage space at the factory will hold from one to three weeks' supply. To enable one to visualize this better, a factory cutting 1000 tons per day would have a storage capacity of 12,000 to 20,000 tons. If the beets were piled 10 ft. deep, the sheds would cover from 60,000 to 100,000 sq. ft. A larger mill would have a correspondingly greater storage space.

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Flumes under the sheds, filled with water, carry the beets to the factory. These flumes are about 16 in. wide and 2 ft. 6 in. deep, and have a one per cent slope. They run the full length of the sheds and are spaced 10 to 12 ft. apart, converging at the lower end into a tail flume leading to the factory. Boards or strips of metal are placed over the flumes before the sheds are filled. After they are full these are removed one at a time and the beets allowed to fall into the water. In a properly designed shed two or three men per shift can supply 1000 to 1500 tons of beets daily. It is necessary that all foreign matter be removed from the beets before slicing, so automatic weed and trash catchers, and devices for removing sand and rocks, are installed in the tail flume.

Washing. After the beets reach the factory they run into a large wheel which elevates them to the washer. The outside is perforated to allow the fluming water to drain off into the sewer. The washer is trough-like in form, and a series of revolving paddles cause the beets to rub against each other until all the dirt is removed. After a thorough washing the beets are elevated by means of a bucket elevator to the top of the mill. They are then weighed in an automatic scale, so that the exact weight of beets entering the factory is known at all times.

Slicing. The sugar in the beets is diffused with water, and in order to insure complete action the beets are cut into long V-shaped or rectangular slices.

Testing. The beets are tested for sugar content and purity just before going to the diffusion battery, and with the sugar content and weight known daily a sugar balance can be run.

Diffusion. The diffusion battery consists of 12, 14, or 16 cells, each holding from three to five tons of sliced beets. The cells are connected up in rotation, the bottom of one cell being connected to the top of another, with a heater between.

For this discussion they will be considered as being in a circle or ring. In fact, in several of the factories they are built in a circle. The sugar is taken from the beet slices by an osmosis action, the walls of the cells acting like parchment and allowing the sugar to pass through to unite with the water, but holding some of the impurities back in the cell, so that a rise in purity of the juice is obtained at this point.

When the diffusion battery is in operation one end holds slices from which the sugar has been nearly exhausted, while the other end contains fresh beet slices. Hot water is introduced into the tail end where it takes up some of the sugar. The water, with a small amount of sugar in solution, then passes through a heater into the next cell in circulation. The beets in this cell contain slightly more sugar so that the water can absorb a small amount from these slices. The water then passes to the next cell in circulation, which is still richer in sugar, and so on until it comes to the cell which has just been filled with fresh beet slices. Here it takes up a further quantity, so that when it leaves the head cell the solution contains from 12 to 14 per cent of sugar in solution.

The beet slices in cell No. 1 are now emptied, and the cell is washed. It is then charged with fresh beet slices, and becomes the head of the battery. Cell No. 2, now the cell where fresh water is introduced, becomes No. 1 in the new cycle; each cell taking a turn at the head position as the process continues.

The water enters the diffusion battery at approximately 50 deg. cent., and is brought up by the heaters between the cells to about 82 deg. cent. The exhausted beet slices, now termed "beet pulp," contain approximately 0.2 per cent sugar, which is lost in the process.

Purification. The juice is now ready for purification. Forty per cent of the soluble impurities should be eliminated in the process to meet the requirements of the factory standards. One pound of impurities will prevent one to one and one-half pounds of sugar from crystallizing, and the impurities and sugar go to form molasses. Most of the purifying (elimination of impurities) is done with lime, but some takes place in the diffusion battery.

After the juice is drawn off from the battery it is measured and the density taken. It is then pumped through closed heaters to the carbonation station, where milk of lime is added to the juice, about $2\frac{1}{2}$ per cent dry lime on beets being added. As soon as the milk of lime is in the tank, carbon dioxide gas is passed through the juice. This precipitates the lime into a calcium carbonate which also takes up a large part of the impurities. When a predetermined alkalinity of the juice is reached the gas is shut off. The juice is then filtered in closed filters to remove all of the calcium carbonate, after which it is sent to the second carbonation station where more carbon dioxide gas is passed through, forming more calcium carbonate, and the gassing process continued until no more precipitate will form. Further filtering follows reheating in a closed heater.

In some plants the juice is boiled vigorously after the second filters to break up any bicarbonates, then filtered a third time. It is then sent to the sulphur station, where sulphur dioxide gas is added as a decolorizing agent and also as a germicide. The alkalinity is further reduced, almost to the point of neutrality. Now the juice, containing from 10 per cent to 12 per cent sugar, and with 40 per cent of the impurities eliminated, is ready for the evaporation station.

Evaporation. Multiple-effect evaporation is used in all factories. Quadruple or quintuple effects are generally used. Steam for the first effect is taken from the exhaust of engines and pumps. All exhaust pipes are run to a common header, and a back pressure of from 10 to 15 lb. is maintained. Make-up steam is supplied from the high-pressure system through a reducing valve as required. The evaporators of a 1000-ton factory will remove two million pounds of water per day, which is indeed a heavy burden. The water is evaporated until a syrup called "thick juice," containing 65 parts solids, comes from the last effect. The thick juice is mixed with melted brown sugar, and sulphur dioxide gas is passed through it, reducing the alkalinity to as near neutral as possible. It is then filtered and sent to the graining pan, where under vacuum further water is evaporated until a supersaturated solution is reached. The grains then begin to form in the pan. The skill of the sugar boiler enables him to control the number of grains and the size. After the constant addition of the new material, which is constantly thickened, a dense mass of the right-sized crystals surrounded by syrup is obtained.

Crystallization. This mass is dropped from the pan into a mixer with slowly revolving paddles to keep it from solidifying. Spouts lead the moisture to centrifugal machines where the sugar is separated from the residue syrup. The centrifugals, while spinning the syrup off, rotate at about 1200 r.p.m. The syrup passes through perforations in the wall of the basket, and the sugar crystals are retained in the basket. After the syrup is spun off, a fine spray of hot water washes away the residue syrup and leaves a white, sparkling crystal. This is then discharged from the basket and sent to a rotary drier where the remaining moisture is removed.

Packing. The finished product is screened to separate the fine and coarse crystals, after which it is weighed in automatic scales and packed in 100-lb. sacks. Most manufacturers also put up sugar in 25-, 10-, and 5-lb. bags, which are baled in 100-lb. sacks. It is then trucked into the warehouse where it is allowed to cool before it is either stacked in large piles or shipped to the market.

Further Treatment of Residue Syrup. The syrup that is spun off from the white centrifugals still contains about 75 per cent sugar. This material is taken to the brown vacuum pan where it is boiled to a supersaturated solution and grained. The grain in this case is kept smaller. After the right-sized grain is formed and the proper density reached this mass is sent to a crystallizer, a horizontal jacketed tank with a very slow-moving scroll. As the mass cools the crystals take up sugar and grow larger. After 50 to 75 hours in the crystallizer the grain is large enough to spin in a centrifugal and make brown sugar.

The resultant product is then dissolved and mixed with the thick juice to make white sugar. The residue syrup from the brown centrifugals is the final molasses.

BY-PRODUCTS

One of the valuable by-products from the sugar factory is the beet pulp, which is an excellent stock food. It is marketed to farmers and feeders either as wet pulp, screened as it comes from the factory, or as pressed pulp, where part of the water is pressed out. It is also sold as dried pulp where it is pressed and then put through a rotary drier and all moisture removed. In all three forms it is highly prized as a stock food.

The beet molasses is the most valuable by-product of the sugar factory. For every 1000 tons of beets cut, 50 tons of molasses,

containing approximately 50 per cent sugar, is produced. Molasses is valued as a stock food, and is also used in the manufacture of yeast and alcohol.

RECOVERY OF SUGAR FROM MOLASSES

It is possible to recover most of the sugar in the molasses by means of the Steffen process. In this process the molasses is diluted with water until it has approximately 12 parts solids per 100. It is then mixed with powdered lime and pulverized to pass 200-mesh screen. During the addition of lime it is kept violently agitated and is also kept at a temperature of from 15 to 20 deg. cent.

Approximately equal parts of lime and sugar are used, and the sugar and lime combine, forming a lime-sugar precipitate called a saccharate. This precipitate is then separated from the solution by filtration, the cake washed, and then used in place of milk of lime in the regular carbonation process. By adding carbon dioxide gas to the beet juice and saccharate the latter is broken down into sugar and calcium carbonate. The sugar passes thus into the regular process.

Barium and strontium can be used in a similar process, but on account of cost have not come into general use. The Great Western Sugar Co. at Johnstown, Colo., is operating a molasses plant using the barium process very successfully. This plant was built in 1926.

SUGAR-FACTORY EQUIPMENT

Standard equipment available in other industries is used in sugar factories whenever possible. The boilers are mostly of the water-tube type. The chain grate stoker with natural draft seems to be the most favored where coal is burned. One factory is using powdered coal, and several use gas and oil. A 1000-ton factory would require 1500 to 1800 boiler hp., while larger and smaller factory boiler houses would be similarly proportioned.

The Corliss-valve-type simple engine is highly favored for motive power, because it runs satisfactorily and efficiently with a high back pressure. The older plants are all belt driven. Some of the newer plants are entirely electrically driven, and some others have electric group drives. Sugar factories have not been electrified to the extent of some of the other industrial plants, because the operations are seasonal and it is difficult to show the necessary savings with a run of only 75 to 120 days per year.

Approximately 12 to 15 centrifugal pumps are used to handle juices and water. The closed impeller, low-speed type seem most favored for this work. Ten to twelve plunger- or piston-type pumps are used for handling the heavy syrups and molasses.

The beet slicers and knives are special machines. They are of European development but are now manufactured in this country.

The diffusion battery and the carbonation tanks are special developments for the beet industry. Heaters are of the multi-pass type. The juice passes through the tubes with the steam in the chamber surrounding the tubes. As the juice is kept at almost a boiling temperature in the entire process, a large number of these are used, the sizes ranging from 500 to 1500 sq. ft. of heating surface.

Filtration is accomplished by the use of pressure-type filters. The plate-and-frame filters are used on third filtration and for thick syrups. The vacuum type is used in the Steffen process. Filtration of the carbonated juices, which was formerly done entirely in pressure filters, is now being handled by the use of thickeners which filter off most of the juice and leave a material which can be handled by vacuum filters even though it is hot.

Both horizontal and vertical evaporators are being used, but the horizontal type seems to be the more popular. In this type the juice is in the body and the steam passes through the tubes. Exhaust steam is used in the first body and the vapor from it does the evaporating in the second, with its vapor passing to the third, etc., so that good thermal efficiency is obtained. Vapors from the various bodies are also used for heating the juices in the closed heaters. First- and second-body vapors especially are used.

Ideas of designers vary somewhat on capacities, but good results are obtained in a quadruple set with about 12 sq. ft. of heating surface in a quintuple set with 15 sq. ft. per ton of beets.

The boiling pans are heated by either coils or calandrias. The coil pans are used exclusively on white sugar, and live steam at 60 to 100 lb. pressure is the heating medium. In the brown pans calandrias using vapor from the first evaporator or exhaust steam are largely used. The coil pans also are used. The sizes of the pans vary from 11 to 14 feet in diameter and hold from 1000 to 1500 cu. ft. All boiling is done under vacuum to prevent caramelization. Centrifugal machines are of the standard top-drive type. The 40-in. diameter is the most popular. Belt drives are the most favored, although some water-motor and direct electric drives are used. Special spray machines for washing sugar have been developed, and also dischargers for unloading the sugar.

As large quantities of lime and carbon dioxide gas are used in the processes, lime rock is burned at the factories. The Belgian-type kiln is most generally used, with coke as fuel. The gas containing about 22 per cent carbon dioxide is taken from the top of the kiln, washed, and compressed to about five pounds pressure. Coke and rock are mixed and elevated to the top of the kiln in a skip, where the charging is done, and the burnt lime is drawn from the bottom of the kiln. Kiln sizes vary from 2000 to 3500 cu. ft. capacity. The shells are of steel with good firebrick linings.

OPERATING STAFF AND REPAIR SHOPS

Each factory maintains a machine and blacksmith shop where repairs can be made. These shops are generally equipped with lathes, shapers, pipe machines, power hack saw, bolt machine, forge, etc., so that all but the large repair jobs can be done at the factories.

The organization of the factory operating staff is important. The yearly crew consists of a superintendent, assistants, foreman and master mechanic, assistant mechanics, and some principal operators, such as sugar boilers. This yearly force varies from 15 to 50 men, depending upon the size of the factory. When operations start in the fall, the crew is built up to about ten times this force. A great number of these operators are experienced men who come back year after year, but it is always necessary to break in a large number of new men. As a factory is expected to start at capacity and avoid serious losses, the supervision and instruction of the force is very important; requiring good organizing ability among the supervisors. As the season is short every one works under pressure, and some remarkable records have been made both in quantity of beets sliced and in repairing serious breakdowns.

Need of Non-Metallic Mineral Industries for Greater Engineering Skill

NON-METALLIC mineral industries demand engineering skill for the solution of their problems. It is hoped that this conviction will gain more ground, for technical progress in metal mining and metallurgy has far outstripped that as yet attained in the field of non-metallics. Problems in the latter field are becoming more complex year by year, partly because of depletion of the more readily available deposits, partly because of the increasing extent of the operations, and in some measure as a result of the demands of the consuming industries, which are becoming more and more exacting. The rigid specifications for the materials of highway construction and for concrete used in public works and buildings demand a refinement in quarrying and preparation that the producing industries would be unable to meet if the crudities common 20 years ago were allowed to persist. There is a wide field in the non-metallic mining industry for engineering ability, and its increasing application will not only improve conditions in the industries themselves, but will promote the general welfare. Construction materials touch the life of every community and every home, and therefore, whatever tends to improve the quality of the raw materials of construction to conserve the resources, or to develop economies in production or manufacture is a direct or indirect advantage to every citizen.

Aside from construction materials there is a group of diverse non-metallics that are attaining wider industrial importance, and that present problems of increasing complexity. Asbestos, for which there is no substitute for the brake bands and clutch facings of our automobiles, mica which is indispensable in radio and electrical equipment, fullers' earth and bentonite for the purification of our oils, phosphate rock and potash so necessary in agriculture—these are a few of the minerals that present many unsolved problems in production, manufacture, and utilization.—*Mining and Metallurgy*, vol. 8, no. 248, August, 1927, p. 343.

Boiler-Feedwater Problems and Methods of Treatment

By SHEPPARD T. POWELL,[1] BALTIMORE, MARYLAND

The paper constitutes a brief survey of the methods employed in the treatment of boiler feedwater for the removal of suspended solids, the elimination of scale-forming salts, purification of make-up by evaporation, and the removal of non-condensable gases for the prevention of corrosion. Continuous blow-down systems and electrolytic scale-prevention appliances are discussed briefly. The phenomena of priming and foaming are also touched upon. The paper concludes with a statement of the work of the Boiler Feedwater Studies Committee, of which the author is Chairman.

GREATER economy in the design and operation of steam-generating equipment has been in the past and still is the impelling motive responsible for the rapid improvement that has taken place in the field of steam engineering within recent years. The condition has been especially pronounced during the past twenty years, and it is indicated that even greater activities along these lines are to be anticipated in the immediate future. Radical changes in boiler and furnace design, higher steam pressures and temperatures, and improvement in the design of prime movers have focused attention upon feedwater treatment. As a result of these conditions, a properly designed feedwater make-up system is now recognized generally as a necessary and important factor in steam generation.

Good water is a relative term and may not be easily defined. Water of satisfactory quality for one purpose may be entirely unsuitable for a dissimilar service. This holds true not only for water employed in the various industries, but when it is to be used for boiler feedwater. An ideal water for steam generation should contain no scale-forming solids, should not cause priming or foaming, and should be non-corrosive. Such supplies are seldom, if ever, obtainable from natural sources. The degree of purification desired depends entirely upon operating conditions. This resolves itself into an economic balance between the cost of treatment and the ultimate return on the investment resulting therefrom.

The primary object of feedwater purification outside of the boiler is twofold, namely:

1 Removal of suspended and soluble solids
2 Removal of gases.

There are numerous other incidental advantages to be gained from such systems, but the major ones may be classified under one of these groups. There are, in addition, many kinds of so-called internal treatment, intended to inhibit scale formation and corrosion. Numerous appliances are available that may accomplish these results more or less efficiently. The engineer is faced with the difficult task of determining not only the relative values of these systems but their specific adaptability under a given set of operating conditions. Lack of fundamental knowledge concerning the functioning of the various systems results, frequently, in the installation of ill-advised treatment plants. It is the purpose of the author merely to indicate the general adaptability of the more important methods of treatment without attempting to designate the type of system for a specific set of conditions.

Removal of Suspended Solids

The oldest and cheapest means of removing suspended solids from water is by plain subsidence. Clarification of muddy water by this method was practiced by the ancient races, and it is still employed widely for this purpose. Plain subsidence should not be considered as a complete feedwater purification system. It has, however, a definite place as an adjunct to feedwater treatment, where the raw water contains a large amount of suspended solids. It is possible, frequently, to effect considerable economy in the operation of chemical softening plants, filters, or evaporators by removing the gross amount of suspended matter by plain sedimentation prior to purification by more elaborate treatment.

The efficiency of subsidence basins depends largely upon the care exercised in their design. The inlet and effluent weirs, the placing of baffles, the designed rates of flow, and many other factors should be considered. The final decision as to use of primary subsidence basins rests upon the unit cost of removal of the settleable solids by this method in comparison with other processes that effect comparable results.

Considerable interest has been taken recently in mechanical thickeners and clarifiers for the removal of settleable solids from feedwater. These appliances are tanks so designed, as to direct by mechanical means the settled solids to one portion of the equipment from which they may be removed continuously or intermittently. The value of these appliances consists in using relatively shallow tanks requiring no appreciable storage capacity in the tank. Tanks of this kind are now being used as subsidence basins, either as plain settling basins, or for coagulation and settling by means of chemicals. They are employed also in cold lime-soda for removal of lime sludges. In many instances they are particularly well suited for this kind of service. The Dorr, Hardinge, and Booth clarifiers are types of equipment that have been adapted to this service.

Filters

Sand filters are used extensively for the elimination of suspended solids either from turbid surface waters or solids carried over from the reaction tanks from chemical softeners. Pressure filters are most commonly employed, although in some large installations gravity filters are in use. Filter design has been fairly well standardized at the present time, and outside of minor specific appurtenances there have been few radical changes in this respect. The most important change in the design of pressure filters recently has been the strainerless filter equipped with a single control valve. This filter is novel, since it contains no strainers or sand valves and the shape of the shell is conical instead of cylindrical.

Chemical Softening

The removal of scale-forming solids from feedwater by means of chemicals has been practiced for many years. The basic principle of this process is relatively simple and is generally well known. It consists of the addition of chemicals to the water to convert the soluble scale-forming salts into insoluble compounds and removing these solids by settling or filtration. Lime and soda, or lime and barium, are generally employed in this country. These processes are fairly well standardized, and the only recent important development other than changes in mechanical equipment is the use of sodium aluminate as an adjunct to the usual softening reagents. It has been demonstrated that with many waters sodium aluminate in small doses may effect a much lower residual hardness in the treated water than can be obtained by straight lime-soda or lime-barium treatment. In some instances the addition of the sodium aluminate reduces the cost of treatment. The process is coming into general use in the treatment of feedwater for locomotives, and many industrial plants have adopted it for softening for industrial or boiler-feed use.

At a few plants preliminary softening by chemicals is followed by zeolite softening. The purpose of these combination systems is the removal of the gross amount of scale-forming solids by the lime-soda or lime-barium and removal of the remainder of the lime and magnesium salts by the zeolite material.

It is frequently more economical to produce satisfactory results in this way than by either method alone. Where such treatment is employed, the preliminary treatment must be carried on in cold water since zeolite softeners do not function satisfactorily with hot water.

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ZEOLITE WATER SOFTENERS

Zeolite water softening has been employed widely in the past for the treatment of water used in a number of industries. This form of treatment is now employed for softening many feedwater supplies. The system is relatively simple, consisting of passing the water through a bed of zeolite mineral that extracts the scale-forming solids from the water and replaces these sodium salts. Since the latter compounds do not form scale, this system is particularly well suited for the treatment of some waters.

After a given amount of sodium is exhausted from the mineral bed and replaced with calcium or magnesium from the water, the unit is cut out of service and the exhausted sodium replaced by sodium chloride (common salt) solution. When the mineral has been regenerated, the excess salt is removed by washing the bed with fresh water and the softener is again ready for service. Zeolite softeners are of practically the same design as pressure filters, in which the filter medium is replaced by the zeolite mineral.

This method of treatment is not suited to all waters. Since all lime and magnesium salts are replaced by sodium, the treatment of very hard waters by these softeners will result in high concentrations of sodium in the softened water. The cost of operation may also be excessive in comparison with other forms of treatment. In most instances the water must be filtered prior to the passage through the zeolite bed, since suspended matter rapidly coats over the grains of the softening mineral, thereby reducing their softening action. In case the raw water is acid, the acidity should be neutralized before attempting to soften the water by zeolite. Water high in iron, free CO_2, or manganese may require preliminary treatment.

Zeolite-softened waters, due to the relatively high concentration of sodium salt, have been held responsible in some cases for the embrittlement of boiler metal. This, however, is still a debatable hypothesis which is not conceded by all engineers. This form of feedwater treatment has a particular sphere of usefulness, and when so applied and properly operated should give satisfactory service. Zeolite softeners are being used to some extent in combination with chemical softeners. A few installations have also been made where the water fed to evaporators is first softened to remove the scale-forming solids. The only value of combination treatment of this kind is in the possible economy to be effected. Removal of the scale-forming solids from the water passing into an evaporator permits better heat transfer by the evaporator coil and may reduce cracking-down periods. Such systems are only warranted under unusual conditions where economy of operation can be demonstrated.

EVAPORATORS

In modern high-pressure plants, the feedwater should be as free from all solids as is practically possible. This is fairly well recognized and the majority of the larger stations and many small ones built recently have made provision to treat the feedwater make-up by the use of evaporators. Theoretically water from evaporators should contain no soluble or suspended solids. This condition is seldom obtained, however, in practice. Distillate from evaporators will contain usually from one-quarter to one grain per gallon of solids. Considering, however, that the percentage of make-up is usually from two to four per cent of the total feedwater, no difficulty from scale-forming solids from this source is probable. From an economic viewpoint, it is difficult to warrant the use of evaporators where the percentage of make-up is in excess of twenty per cent of the total volume of feedwater.

Evaporators may be either high- or low-pressure or may be single-effect or multiple-effect units. The choice of the type of evaporator to be used should rest entirely upon the heat balance of the station and the ultimate economy that may result from the installation. These facts may be determined only as the result of a comprehensive engineering study of station conditions. The factors to be considered in an investigation of this kind should include—

1 The maximum percentage of make-up water
2 The nature of the raw water
3 The feedwater-heating equipment
4 The estimated condenser leakage and the nature of the impurities that may be carried into the make-up from this source
5 The maximum, minimum, and average load on the station
6 The source or sources of exhaust steam other than from prime movers
7 The relative cost of installation and operation in comparison with other feedwater-purification equipment.

There are numerous other incidental items that will be apparent in specific instances.

Aside from all other considerations, there is a definite trend toward the employment of evaporators to furnish make-up water to all high-pressure boilers. It is difficult to predict what the chemical reaction of solids in water may result at extremely high temperatures and pressures. For this reason the necessity for make-up water containing as little solids as possible is recognized. As has been stated, an intelligent decision as to the installation of this type of feedwater treatment may be made only as a result of careful study of local conditions.

DEAERATORS

Experience in steam engineering has demonstrated the importance of complete deaeration of feedwater. The removal of non-condensable gases from feedwater is now considered a necessary precaution to inhibit corrosion of boilers and appurtenances and to insure efficient surface-condenser operations. It is a well-known fact that oxygen and carbon-dioxide gas, two gases generally present in all natural waters, are active accelerating agents of corrosion. Where the feedwater make-up carries scale-forming solids, the tubes and sheet of boiler are protected from the corrosive action of these gases. When the incrustants are removed from the water by external treatment, the metal may be entirely free from scale. Under these conditions, oxygen and other non-condensable gases coming into direct contact with the metal set up an active corrosion. To inhibit this action, it is essential completely to deaerate the feedwater before it enters the system. Open feedwater heaters and chemical treatment of the feedwater that is carried out in hot solution effect a fairly high removal of these gases. Dissolved gases are not completely removed, however, by these appliances, so that in many steam plants it has been found necessary to install deaerators or deaerating heaters. By these apparatus practically complete removal of gases can be obtained.

In addition to the corrosion that may result in economizers and boilers from non-condensable gases in the feedwater, other operating difficulties can be traced to this source. The corrosion of superheater tubes and steam lines is frequently traceable to this source. Non-condensable gases are responsible also at times for poor condenser performance due to the blanketing of the tubes, thereby, resulting in poor heat transfer. Removal of gases carried over to the condenser from the boiler imposes frequently heavy duty upon the air-ejector equipment. These factors are of importance in considering the economic balance and the financial returns chargeable to the deaerating system.

CONTINUOUS BLOW-DOWN SYSTEMS

In an effort to achieve greater economy of boiler operation, attention has been directed lately to continuous blow-down schemes. Blowing down of boilers to inhibit too high concentration of soluble and suspended solids is a necessary operation, but entails losses that in a large plant may be relatively great in a year's time. The major loss is due to the heat in the blow-down water discharged to the sewer. The value of the water blown down, the wear on the valves, and other incidental losses are also important factors to be considered.

A number of appliances for the purpose of reducing these losses have been placed upon the market within the past two or three years. Some of these schemes are ingenious, and when properly applied are warranted. Other appliances designed for this kind of service have little real merit. One type of continuous blow-down is essentially a small pressure filter, through which the blow-down water is filtered and returned to the boiler without appreciable loss of heat. The equipment removes the suspended solids and the clarified blow-down water with the soluble solids is returned to the boiler. The value of the system is the saving effected by removing the suspended solids thrown out of solution in the boiler and the removal of these constituents without loss of heat.

There are at least two continuous blow-down systems that are

designed to utilize the heat released from the blow-downs to heat the feedwater in specially designed heat exchangers. In one of these schemes, a two-pass heat exchanger is used. The cold raw water enters the unit on its way to the heater and the discharge from the heater then flows through the first pass on its way to the boiler.

Much more elaborate blow-down systems are being utilized in Europe, and one of these systems is now being offered to the American trade. In these systems the blow-down water is used to heat the raw water in hot chemical softeners. By this scheme the solids discharged from the boilers are said to aid in softening, and less live or exhaust steam is required to bring the water up to the desired temperature.

Continuous blow-down systems have merit, and, when properly designed and operated, can produce sufficient economy of operation to warrant their installation. An an adjunct to other methods of feedwater treatment, it is indicated from the data now available that these appliances have a specific sphere of usefulness.

Electrolytic Scale-Prevention Appliances

Much has appeared in the technical press recently concerning electrolytic processes for the inhibition of scale and corrosion in boilers, condensers, and heaters. Up to the present time, six systems of this kind have come to the author's attention. A number of these installations have been made in this country and abroad. No uniformity of opinion exists among investigators as to the value of these appliances. In some instances good results were obtained, while others have reported that the value of the process was doubtful. In one or two cases it has been stated that corrosion was accelerated.

A rather extensive investigation has just been completed at one of the large public utilities in this country. An experimental boiler was constructed and operated under the joint supervision of the manufacturer and the company. The results of this test have not yet been made public. It was learned by a private communication, however, that the system completely stopped all scale formation in the drum of the boiler but the tubes scaled up rapidly. The same type of system has proved satisfactory, however, in inhibiting corrosion in open heaters. A number of electrolytic processes are being tested on locomotives, but definite conclusions as to the merit of these systems have not yet been obtained.

Internal Treatment

This form of boiler-water treatment has been employed from the earliest use of steam boilers. Under this heading is to be classed the great variety of boiler compounds and the numerous types of treatment employing sodium salts. In the majority of instances, external treatment of feedwater is preferable to the use of compounds. There are cases, however, where the direct application of chemical to boiler water is warranted. When this form of treatment is intelligently controlled, relatively good results are possible. The principal objection to the use of compounds is the indiscriminate use of materials of unknown composition. Many of these products are useless and may result in serious operating difficulties.

A number of scientific investigations have been carried on to determine the specific value of sodium compounds and similar materials for the inhibition of scale formation and corrosion. These data have demonstrated the specific value of such treatment and its limitation. Many products have been placed upon the market recently that have some value in preventing the formation of hard scale. These substances are mostly organic products that inhibit the adherence of scale-forming solids, maintaining these salts in the form of sludge. Colloidal compounds are to be classed in this group. Sodium aluminate has recently been applied successfully in a number of installations.

Problems are encountered in steam generation that in a strict interpretation may not constitute feedwater treatment. Many of these difficulties are closely allied with the composition of the make-up water, however, and may not logically be divorced from the subject. The more important operating difficulties are priming and foaming, embrittlement of boiler metal, and various forms of corrosion. Equipment designed for controlling these factors or methods of operation devised to inhibit such action should therefore be placed under the general classification of feedwater treatment.

Priming and Foaming

This phenomenon is familiar to all operating engineers. It is surprising, however, to find how little definite knowledge is available concerning the actual conditions responsible for these troubles. It is believed generally that sodium salts are responsible for all priming and foaming. These salts and other soluble compounds are undoubtedly contributing factors. Recent experimental investigations, however, have demonstrated that many other factors are of importance and may not be ignored. The nature and degree of fineness of the suspended solids, the ratio of the soluble to the suspended solids, and many other items enter into the problem.

In addition to the chemical and physical qualities of the feedwater there are numerous structural and operating details that are responsible in part for the priming and foaming of boiler waters. Treatment of the feedwater may inhibit the tendency toward priming and foaming or may increase this action. Removal of suspended solids improves conditions and increasing soluble salts, particularly sodium compounds, under some conditions, accelerates the phenomenon.

It is common practice to blow down boilers at intervals to maintain a concentration in the boiler sufficiently low so as to minimize the amount of moisture carried from the boiler. This is a relatively costly operation and frequently results in an appreciable financial loss in a short time. It is necessary in most cases to blow down boilers, but a careful study of conditions and proper treatment of the feedwater may reduce greatly the quantity of water blown down.

Steam purifiers are coming into use rapidly. The purpose of these appliances is to remove the moisture and solids from steam by mechanical means. There are several manufacturers of this kind of equipment. In many cases the installation of steam purifiers is warranted, since the saving resulting from dry steam free from impurities eliminates many heavy losses throughout the steam cycle. These appurtenances may not be considered "cure-alls" but when employed in conjunction with proper feedwater conditioning are of specific value.

Corrosion of boilers and of similar equipment and to a lesser degree the embrittlement of boiler metal, are definite problems that cause much annoyance in some stations. These operating difficulties are complicated, involving not only the feedwater but numerous other factors. To what extent the feedwater is responsible is not always apparent. Where such troubles are encountered, a careful investigation of all conditions should be made since a solution may be obtained only in this way.

Corrosion of boilers and appurtenances is often the result of improper feedwater treatment or failure to provide any form of treatment. The most important single factor accelerating corrosion is oxygen. The removal of oxygen from feedwater may not competely inhibit corrosion, since other constituents in water are contributory agents. The removal of oxygen will reduce merely the rate of corrosion in proportion to its specific effect.

Boiler Feedwater Studies Committee

Recently, the importance of boiler-feedwater purification has focused the attention of many individuals and groups of engineers upon this important subject. There has developed an insistent demand for fundamental information of the chemistry of water as related to feedwater problems. As a result of this need, a comprehensive study of this subject was undertaken about three years ago by a group of engineers and chemists interested in these various problems. The movement has been expanded until at the present time it is sponsored, as a joint study, by six of the major engineering organizations interested directly or indirectly in the various phases of this work.

The following societies now have representatives on the various committees:

The American Society of Mechanical Engineers
The National Electric Light Association
The American Water Works Association
The American Railway Engineering Association
The American Boiler Manufacturers Association, and
The American Society for Testing Materials.

The purpose of the movement is to collect information on the various forms of feedwater treatment, to study and to report upon the value of new processes, and to correlate operation and theoretical data. This information is to be published yearly in the form of progress reports. These reports will be printed in the journals of the various technical societies affiliated in the work and in the technical press.

The first progress reports[2] were presented at the fall meeting of The American Society of Mechanical Engineers in New York last year. These have since been published also in full or in part in a number of technical journals.

The organization consists of an Advisory and Editing Committee and nine sub-committees. A study of the various problems has been assigned to the nine sub-committees, whose duty it is to give attention to the specific problems. A brief classification of these problems is as follows:

1 Filters, deconcentrators, plain subsidence and coagulation, continuous blow-down apparatus
2 Softening by chemicals
3 Zeolite softening, internal treatment, priming and foaming, and electrolytic treatment
4 Evaporators and deaerators
5 Corrosion
6 Embrittlement
7 Treatment of municipal water supply and the effect of trade waste on feedwater treatment
8 Standardization of water analyses applicable to feedwater
9 Current bibliography of articles relating to feedwater treatment.

It has been recognized by all who have given thought to this subject that many of the problems under consideration by the committees are highly technical and that their solutions will require well-conducted research investigations.

Plans are now being formulated to create fellowships in a number of universities equipped for work of this kind where such studies may be made. The Finance Committee is now studying the possible means of creating a sufficient fund to carry on these investigations for a five-year period.

It is desired that this academic work may be carried on jointly with field studies on a practical scale, either through the coöperation of the steam railroads or in stationary steam stations equipped for such work.

Until recently, specific knowledge on the treatment of feedwater was in the twilight zone. It is rapidly being recognized as an exact science and of the greatest importance in power-plant design and operation. It is through the coöperative effort of the various engineering societies that definite and accurate knowledge on the subject may be possible. It is the desire of those who are carrying this work forward that through such coöperation, solutions will be found for the many difficult feedwater problems now beyond control.

Discussion

F. H. THORNE,[3] presented the results of some research on K.W.S. sodium aluminate. In an external softening plant the sodium aluminate was used: first, because it shortened the time required to obtain complete reaction of all chemicals used. As an example, various tests made in cold-process intermittent-type plants proved that samples of water taken at the time agitation was stopped showed no change in analysis from samples taken 48 hours later.

Second, a lower range of hardness could be maintained with less excess lime and soda ash. In a cold-process intermittent-type plant a tank containing 155,000 gal. of a highly turbid raw water with a hardness of 8.3, was treated with 170 lb. of lime, 230 lb. of soda ash, and 70 lb. of iron. This treatment reduced the hardness to 1.5 with a hydrate excess of 1.5 and a soda-ash excess of 2.0 in grains per gallon.

A similar test was made under identical conditions using lime, soda ash, and K.W.S. sodium aluminate. With this treatment the water was reduced to 0.5 of a grain of hardness with excess hydrate of only 0.3, and excess soda ash of only 1.1. This water was produced with only 75 lb. of lime, 146 lb. of soda ash, and 36 lb. of K.W.S. sodium aluminate, showing a reduction in lime of 95 lb., a reduction in soda ash of 84 lb., and with the 36 lb. of K.W.S. sodium aluminate replacing the 70 lb. of ferrous sulphate used in the previous treatment. With the iron treatment the total excess of hardness and chemicals in the treated water gave a total alkalinity of 5.0 grains per gallon, while with the K.W.S. sodium-aluminate treatment, these excesses gave a total alkalinity of only 1.9 grains per gallon, and at least cost per 1000 gal. of water.

Third, the total solids in the treated water could be materially reduced. In a cold-process intermittent plant a 150,000-gal. tank was treated with lime, soda ash, and iron under practically ideal conditions. The resulting water showed on analysis of 1.0 grain per gallon of hardness, 1.0 grain of hydrate excess, and 1.0 grain of sodium-carbonate excess. For the purpose of research, an identical raw water was treated in the same equipment, and the lime, soda ash, and K.S.W. sodium aluminate were so apportioned as to produce identical excesses, viz., hardness of 1.0 grain, hydrate excess of 1.0 grain, and soda-ash excess of 1.0 grain. Evaporation tests made on these samples of water showed that the water treated with iron contained total solids of 17.6 grains per gallon, while that treated with K.W.S. sodium aluminate contained total solids of only 10.5 grains per gallon.

The possible reduction in blow-down was of course obvious, and in fact proved itself practical in actual operation.

For use as an internal treatment, Mr. Thorne said, K.W.S. sodium aluminate was used only in sufficient quantities to give proper coagulation in the mass of boiler water. No attempt has been made to use it as a "cure-all." Once proper coagulation was obtained by a given dosage per volume of water, the remaining hardness as shown by analysis could be reduced normally with soda ash, or any other chemical which might be necessary to bring the final softening reaction to completion.

The principles used in treating water externally were therefore applied to an internal treatment. Samples were drawn at regular intervals, and their analysis would show an over or under treatment, which might be due to a change in load or composition of the boiler feed. The variation could be immediately noted and proper adjustment made at once.

As with any other chemical, successful operation with K.W.S. sodium aluminate was only measured by the intelligence with which it was handled. Simple equipment and methods had been designed to furnish satisfactory volumetric analysis requiring only 15 to 20 min. a day.

Washability of Fine Sizes of Coal on Tables

THE purpose of this work conducted at the Northwest Experiment Station is to make a fundamental study of coal tabling, using float-and-sink tests of zonal products supplemented by screen-sizing tests and chemical analyses.

As a result of this investigation to date, methods and apparatus have been developed by which a low-ash coal can be produced efficiently from the bony coals of the Pacific Northwest; also considerable progress has been made in increasing the capacity of the table. The two most important results of the work have been (1) the development of a special system of high, closely spaced riffles for the table, and (2) the development of a hindered-settling classifier possessing the refinements and large capacity necessary for treating coal. Both of these developments have proved remarkably efficacious in increasing both the efficiency and capacity of the table.

The results of washing a carload of coal at Seattle demonstrated that the ash in the washed coal could be appreciably lowered, thus effecting a material saving per year many times the cost of the investigation; also that the improved methods of washing fine coal developed during this work in the Pacific Northwest have a wide application in other fields of the United States.—Byron M. Bird in Notes from the Bureau of Mines, communicated by the Director and published in the *Journal of The Franklin Institute*, August, 1927, p. 273.

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[2] See MECHANICAL ENGINEERING, Mid-November (1926) issue, vol. 48, no. 11a, p. 1361.

[3] Field Manager, Chicago Chemical Co., Chicago, Ill.

Personnel Administration in the Steel Industry

By F. V. LARKIN,[1] BETHLEHEM, PA.

PERSONNEL administration in the steel industry, as developed in this paper, may be put into the form of the interrogation, "How is scientific management applied to men in the steel industry and does it pay?"

Scientific management, conceived by Taylor and put into operation by him and his associates during the last quarter of the nineteenth century, had more to do with materials and processes than with human beings and their relationship to industry. By 1912 the idea was pretty widely accepted and its fundamental principles quite generally put into operation in some form by the more progressive industries of the county.

The soundness of these principles, and the results which followed their skilful administration, did much to pave the way toward a consideration of the possibilities which might be expected from the application of these same principles to the human side of industry. Just when the phrase "personnel administration" was coined to sum up those principles of scientific management having to do with human beings, or the individual who first introduced it, is of little moment. As defined by Tead and Metcalf:[2] "Personnel administration is the planning, supervision, direction, and coördination of those activities of an organization which contribute to realizing the defined ends of that organization with a minimum of human effort and friction, with an animating spirit of coöperation, and with proper regard for the genuine well-being of all members of the organization."

It is the purpose of this paper to indicate the scope of personnel administration as it exists today, to review briefly the history of the steel industry since the introduction of personnel administration, and to indicate the trend of some of the factors which may be taken as a measure of its effectiveness.

The steel industry manifested an interest in personnel administration shortly after the formation of the United States Steel Corporation in 1901. In 1906 an investigation of the safety and welfare activities of the subsidiary companies of that corporation led to the appointment of a committee to study welfare matters. In 1908 Judge Gary, in an address to the casualty managers of the different subsidiary companies, indicated the willingness of the corporation to appropriate funds to put into effect practicable suggestions for the improvement of welfare conditions at the various plants. In 1911 the Bureau of Safety, Sanitation, and Welfare was inaugurated. Since that time personnel administration has been extended throughout the steel industry until today it has to do quite generally with all employees during their term of service through the following logical and more or less definite subdivisions:

1 Department of Employment
2 Department of Safety and Welfare
3 Department of Education
4 Department of Employee's Service
5 Department of Employee's Representation.

Throughout the industry it is now general practice for the employment department to interview and hire employees, to require a physical examination by the welfare department, and to direct new employees to occupations in keeping with their physical and mental aptitudes. Cases requiring subsequent medical attention are followed up, progress records are maintained, and as a general thing all terminating employees are interviewed by the department, with the idea of insuring fair treatment to all, and for the purpose of analyzing the causes of terminations.

Undoubtedly the greatest achievement of personnel administration in the steel industry has been effected in the department of safety and welfare. From the standpoint of safety it is common practice to provide periodic and systematic inspections of plant and equipment by committees of workmen; complete reports of all accidents; measures looking to accident prevention through the provision of safeguards against machine hazards, fire hazards and hazards peculiar to specific occupations; education in safety; and complete statistical data on all incidents bearing upon the safety of the employees. From the standpoint of welfare it is likewise common practice to provide adequate medical and nursing staff to conduct the physical examinations of applicants under consideration by the employment department, to care for minor injuries and indispositions as they occur, and to provide first-class hospital treatment in cases of major accidents. In addition the welfare department maintains a general oversight of employees exposed to occupational hazards, supervises the payment of compensation for injury, and exercises a general supervision over all working conditions.

That subdivision of personnel administration referred to as the department of education is not as thoroughly organized and isolated in the steel industry as are the departments of employment and safety and welfare already discussed. Apprentice courses are almost universal either within the plants or by coöperation with outside educational institutions. Americanization classes are conducted where the number of alien employees is large. Night classes for foremen, draftsmen, and apprentices are widely provided, often in coöperation with a local Y.M.C.A., trade school, or university. More recently the selection, training, placement, and general oversight of relatively large numbers of college graduates under the guidance of a competent executive has become an annual custom. While the details of this latter function vary widely, the general practice is common.

Whether or not a department of employee's service is set up as a separate entity, it is common practice throughout the steel industry to look with favor upon a reasonable activity in the operation of athletic teams, musical clubs, dramatic organizations, and the like. Within the scope of this department logically come the supervision of mutual-benefit associations, supervision of company housing, coöperative purchasing, loans for the purchase of homes, supervision of the purchase of company stock by employees, and a general municipal coöperation in the adequate maintenance of public, health, education, and transportation.

The department of employee's representation, sometimes known as the department of joint control, while existing in some instances as a definite subdivision and headed up by a staff officer carrying the title of management's representative, is still less general. Where such a department exists it serves as a clearing house for the adjusment of matters pertaining to conditions of employment, adoption and enforcement of shop rules, hours of service, wages, grievances, complaints, and discharge. The head of this department has coöperative supervision over shop committees, committee functions, and operates as a buffer between workmen and management on the one hand, and management and workmen on the other.

The United States Steel Corporation, whose production is about 45 per cent of the total, indicates the scope and cost of this program of personnel administration in that organization as follows:[3]

Number of dwellings and boarding houses constructed and leased to employees at low rates	28,216
Churches	27
Schools	32
Clubs	39
Restaurants and lunch rooms	66
Rest and waiting rooms	280
Playgrounds	169
Swimming pools	19
Athletic fields	114
Tennis courts	99
Band stands	17
Practical housekeeping centers	32
Piped systems for drinking water	487
Sanitary drinking fountains	4,689
Wells and springs protected against pollution	887
Comfort stations (complete units, either bath or dry houses, closets, wash or locker rooms, in separate buildings or within enclosures in the building)	2,130

[1] Director of Mechanical Engineering, Lehigh University. Mem. A.S.M.E.

[2] Tead & Metcalf, Personnel Administration, McGraw-Hill, 1926.

Presented at the Kansas City Meeting, Kansas City, Mo., April 4 to 6, 1927, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[3] United States Steel Corporation, Bulletin 11.

Water-closet bowls	10,375
Washing faucets or basins	24,930
Showers	4,810
Urinals	3,799
Clothes lockers	179,581
Base hospitals	11
Emergency stations	383
Training stations (first-aid and rescue)	58
Company surgeons, physicians, and internes	233
Outside surgeons (on a salary)	117
Nurses (including nurses in training)	251
Orderlies and other attendants	110
Visiting nurses	62
Teachers and instructors	208
Sanitary inspectors	40
Safety inspectors (spending entire time on work)	162
Employees who have served on safety committees	119,875
Employees now serving on safety committees	9,485
Employees who have been trained in first-aid and rescue work	21,731
Employees now in training	396

WELFARE EXPENDITURES

(Jan. 1, 1912 to Dec. 31, 1925)

Playgrounds, schools, clubs, gardens, visiting nurses, etc		$27,970,411
Sanitation		31,721,034
Accident prevention		15,698,604
Relief for injured men and the families of men killed		45,660,691
The Employees' Stock Subscription Plan		22,564,858
For pension fund payments in excess of income provided by permanent fund		6,572,445
Total pension payment to employees[1]	$13,014,343	
Additional benefit payments and administration cost[1]	509,338	
For the creation of permanent fund		8,000,000
Total		$158,188,043

[1] Not included in total.

While data are not available for indicating the scope and cost of the program of personnel administration throughout the industry, it is significant that the industry as a whole has followed the lead of the larger corporations as prosperity has made it possible or as necessity has made it imperative, until today the principles of personnel administration are recognized and adopted generally, with a degree of elaboration depending upon the zeal of those charged with its administration and the faith of those charged with appropriating the funds.

It has taken the steel industry just about twenty-five years to evolve this program. During that time a number of things have transpired that merit attention and consideration:[4]

1 Steel production has multiplied 300 per cent
2 Wage earners to effect this production have multiplied 167 per cent
3 Average wages per employee have multiplied 250 per cent
4 Productivity per worker has multiplied 150 per cent
5 Accident rate has been reduced by 50 per cent, thereby saving from injury an estimated number of 500,000 men in the last fifteen years
6 Hours of labor have decreased, the standard toward which which the industry is striving being 8 hours per day and, generally speaking, 44 hours per week
7 Strikes and lockouts in the industry have decreased from 72 in 1916 to 7 in 1925.

During this time the industry has enjoyed an unparalleled period of expansion and profit taking. Following the decision to abolish the twelve-hour shift, in 1923 the Corporation paid an extra dividend of 3/4 of 1 per cent, in 1924 an extra dividend of 2 per cent; in 1925 it raised the regular dividend on common stock from 5 to 7 per cent; and in 1926 it distributed to common stockholders an extra special dividend amounting to 40 per cent of the then outstanding shares and worth at par over $200,000,000.

This financial response cannot be attributed to any single phase of the program of personnel administration, nor entirely to the program itself. It is the result of a careful plan, well conceived and skilfully operated, since its inception twenty-five years ago.

Some economists state that it was they who forced this entire program of personnel administration by laying the groundwork for the political enactment of workmen's compensation; politicians of both parties tell the story to their own advantage; the church points with pride to its investigation and report on the steel strike of 1919; but the fact remains that engineering research, with its scientific, accurate, painstaking analysis, and experiment must, in the end, be credited with having laid the foundation stones of personnel administration within the steel industry four years before the enactment of the first workmen's compensation law. Engineers have learned to apply scientific management to men, and the result has been a success.

[4] Data from U.S. Census, U.S. Department of Labor U.S.S.C. Bulletin 11.

Discussion

F. G. BUFFE[5] spoke of personnel relations in the Kansas City Public Service Company. He said that his company had disguised its welfare work and had featured the fact that benefits to the employee were possible because of coöperation. The employee activities, he said, were paid for and operated by the men. The employees' representation system had been in operation for eight years, and difficulty had been found in keeping the committees busy. He felt that the dreams of visionaries had been responsible for the era of personnel administration, although he admitted that engineers "knew a good thing when they saw it."

Howard A. Fitch[6] wrote that apparently the aim of the United States Steel Corporation had been to provide for the bodily comforts and necessities of their employees.

Not only the United States Steel Corporation, but other large industrial concerns, had spent much effort in heralding their accomplishments along these lines, so much so, in fact, that there seemed to be a tinge of philanthropy attached to them. Until these ideas were dissipated, and until the managements of large corporations came to a realization that these things were a prime necessity in the operation of any institution, and not a matter for self-glorification, no great further progress would be made in solving the problem of human relationships in industry.

In the matter of safety research and application, he said, the Steel Corporation had made a great contribution. Perhaps more than any other factor, the Steel Corporation was responsible for the splendid advancement in safety-first propaganda.

Mr. Fitch's definition of personnel administration was as follows: Personnel administration is the effort on the part of the management to make of those people who happen to be in its employ, better men, more efficient men, and thereby more contented and happy men.

The first responsibility of an employer, and the most important consideration from the standpoint of the employee, was steady work. Employers must come to a realization of this responsibility. It involved the adoption and application of a proper business policy. It touched the determination of the amount of profit a concern should make. It required a careful consideration of "The Philosophy of the Surplus."

Employers should realize that they were obligated to make a sufficient profit to take care of all their obligations. These obligations were not limited to banks and stockholders, but to industry, to the organization, and to the city.

It was most vital in any man's life and happiness that he love his work. Personnel activities should therefore concentrate on a study of an employee's adaptibility for certain work. Employees should be given opportunities for advancement according to their capabilities. They should be shifted from one job to another until they found one for which they were more especially adapted.

Forrest E. Jones[7] said that it had been possible to reduce the cost of power at the power plant of the Kansas City Public Service Company below a figure which the engineers had considered possible because of the personnel relations which existed in the plant. The management of the plant was virtually in the hands of the foremen. At weekly meetings of the foremen, problems in operation were discussed and the recommendations were carried to the men through the foremen.

[5] Vice-President, Kansas City Public Service Co., Kansas City, Mo.
[6] Kansas City Structural Steel Company, Kansas City, Mo.
[7] Assistant Result Engineer, Kansas City Public Service Company, Kansas City, Mo.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The DeHavilland Differential Aileron

WHILE this device has been known since 1923, it is said it is not yet generally well understood. The effectiveness of this form of control depends upon securing precisely the correct relation between the movement of the down-going and the up-going aileron. This relation determines not only the effectiveness of this form of aileron but also the amount of automatic balancing which is produced.

In the most recent machines of the DeHavilland Company a differential aileron gear has been used which gives almost perfect aileron balance, consequently a very light control, and at the same time a control at least as powerful as the normal type of aileron at ordinary speeds, and one which is entirely effective at and beyond the stalling angle of the machine.

The usual form of aileron fails to be effective at the stall, not because movement of the ailerons ceases to change the lift of the two sides of the wing in the required way, but because such movement causes a very largely increased drag on the side of the wing of which the aileron is pulled down. This increased drag on the low wing slows up that wing, and the required increase of lift is lost because the air speed of the wing on that side is reduced. If the airplane has a rudder powerful enough to overcome the increased drag of this low wing, and therefore to prevent this slowing-up effect, ordinary ailerons are effective.

From this it will be obvious that the measure of the effectiveness of an aileron or other form of lateral control can be measured by the ratio between the lateral righting couple—or "rolling moment"—and the turning couple—or "yawing moment"—which it produces under any given circumstances.

Where both ailerons move in opposite directions through the same angle, both the rolling moment and the yawing moment produced increase roughly in direct proportion to the angular displacement of each aileron. The ratio between these two moments depends on the incidence of the wing as a whole. And as stalling is approached, the yawing moment increases, and the rolling moment decreases for a given aileron displacement.

In the differential control, the aileron on the wing tip which the pilot desires to raise is moved downward at a slower rate than that at which the aileron on the opposite tip is raised. As a result a greater proportion of the rolling moment is in this case produced by reducing the lift on the high wing.

At the same time the increase of drag on the low wing is less, because for a given rolling moment the downward-moving flap has not been moved so far. On the other hand, the increased movement of the up-going flap increases the drag of the high wing, and so tends to produce a reversed yaw.

If a large movement of the control stick is made the down-going aileron ceases to move downward and then begins to move up again. When this happens all the increased rolling moment is provided by reducing lift on the high wing, the drag of the low wing ceases to increase, and begins to decrease, but the drag of the high wing goes on increasing.

As a result, such a large movement of the control produces a rolling moment which goes on increasing, but a yawing moment which decreases. And this is precisely what is required to give effective aileron control when stalled.

The original article illustrates the motions of the flaps for a given movement of the pilot's hands in several types of planes. It is stated that in the Hercules plane the automatic balancing effect is so complete with the ratio of motion between the two ailerons selected that the wheel may be put into any position and left there. All the controls in this machine run on ball bearings and the friction is very small indeed, but it is sufficient to hold against the unbalanced loads on the ailerons.

The differential movement generally is secured purely and entirely by the correct selection of the angular relations between various members of the aileron operating mechanism. In this way a saving is obtained in weight, resistance, and simplicity of construction. Fig. 1 shows diagrammatically the essential relations of the various parts of the aileron-operating gear which is used on the "Stag." In this sketch the distance between the differential gear center and the aileron hinge center and the radius from the aileron hinge to the end of the aileron lever are given as multiples of the ratios of the lever of the differential gear. (*The Aeroplane*, vol. 32, no. 26, June 29, 1927, pp. 774, 776, and 778, 5 figs., *d*)

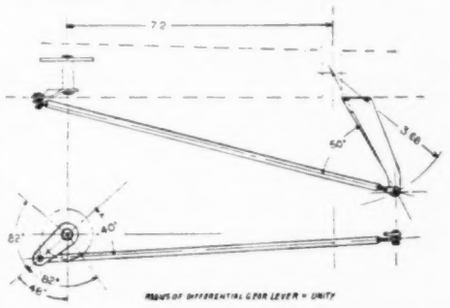

FIG. 1 DIAGRAM OF THE DIFFERENTIAL GEAR USED ON THE DEHAVILLAND "STAG"

AIR ENGINEERING

Refrigerating Turbo Compressor for 6,000,000 Kilo-Calories per Hour

THE TURBO compressor described here is the first used with ammonia in a refrigerating plant and is dimensioned for a full load of 6,000,000 kilo-calories per hour. The plant is employed to separate crude potassium salts by crystallization from the lye. Had a reciprocating machine been installed instead, a very expensive compressor of exceedingly large dimensions would have been needed to fulfil the conditions in this installation. The present compressor is a three-cylinder set with separate intercoolers between the low- and intermediate-pressure cylinders and between the intermediate- and high-pressure cylinders. The compressor runs between the temperature limits of —15 deg. cent. and +30 deg. cent., the suction pressure being about 2.41 kg. per sq. cm. abs. (34.27 lb. per sq. in. abs.) and the delivery pressure about 11.9 kg. per sq. cm. abs. (169.2 lb. per sq. in. abs.). The suction volume is about 175 cu. m. (6119.9 cu. ft.) per min. and the full-load rating about 2300 hp. at 6000 r.p.m.

A two-cylinder extraction turbine is used to drive the machine. The turbine can run as a pure back-pressure turbine with the low-pressure cylinder shut down, or as a condensing turbine with the low-pressure cylinder in operation, a surface condenser being installed for the latter case. The compressor is fitted with the Brown Boveri movable-diffuser regulation, which enables the volume to be varied within wide limits so that the refrigerating capacity of the plant can be adjusted from about three to eight million kilo-calories per hour. This great range of regulation, which could not nearly be approached with reciprocating compressors, is an important advantage in refrigerating plants. (R. Gilly in *The Brown Boveri Review*, vol. 14, no. 6, June, 1927, pp. 160–161, 1 fig., *d*)

ENGINEERING MATERIALS

Effects of Temperature and Humidity on the Properties of Cements and Mixtures

GENERAL conclusions obtained from the various experiments described in this paper are in part summarized as follows:

The compressive strength of mortar both with and without an admixture such as volcanic ash and infusorial earth is raised by heating

up to about 300 deg. cent. (572 deg. fahr.), the increase of strength varies from 20 to 150 per cent according to the kind of mortar, and the greatest strength ratio is raised generally in accordance with the smaller amount of cement in the mixture. Quenching always reduces the strength got by heating. Loss of strength in every mortar by heating, and especially by quenching at a high temperature such as 800 deg. cent. or more, is decidedly greater. The mortar containing an admixture is more fire resistant relatively than the cement mortar in some region of heating temperature since the rate of decrease of strength due to heating and quenching in the former is less than that in the latter.

The compressive strength of concrete is increased also by heating it up to 400 deg. cent. (752 deg. fahr.) and by quenching up to 200 deg. cent. (392 deg. fahr.) and then the strength continues to decrease until the highest temperature of 900 deg. cent. (1652 deg. fahr.) is reached, more remarkably by quenching.

The tensile strength of neat cement is always decreased both by heating and by quenching; cement mortar, however, gains strength up to 200 deg. cent. or more by heating and up to 100 deg. cent. or more by quenching, and hence the latter is more fire resistant than the former.

Gravel concrete has a very low thermal conductivity and the proportion of the concrete has no remarkable effect on the thermal conductivity, except that in a lean mixture such as 1:4:8 it is a little less than in the other. The distribution of heat is not uniform in the concrete, being greater at the part near to the heated surface.

The rate of heat transmission through the concrete mass may be expressed approximately by the following equation:

$$y = \frac{\alpha}{\beta + x} - \gamma$$

in which the constants α, β, and γ vary with the proportions of the concrete, using the same cement and aggregates, and the temperature at the exposed surface. Since the concrete receives a less effect of temperature in its interior part than at the outer surface, the deformation of the concrete due to the temperature change should be considerably less than that generally believed. Any reinforcement used to prevent the crack produced by temperature change in the concrete should be inserted as near as possible to the exposed surface, and the thermal stress actually produced in there inforcement by such a cause should be appreciably less than that calculated from the usual formula; the error, however, is always on the safe side.

Atmospheric temperature has a remarkable effect on the setting time of cement both with and without any admixture. The lower temperature retards and the higher temperature accelerates the time of set, both initial and final. The rate of variation, however, is not uniform; being greater at the lower temperature. The general formula showing the velocity of chemical reaction

$$\log \frac{1}{z} = -\frac{\alpha}{273 + t} + \beta$$

is also applicable to express the relation between the atmospheric temperature and the setting time in cement either with or without an admixture. Tetmajer's formula

$$z = \frac{a}{b + t} + c$$

and the author's formula

$$z = a + bt + ct^2$$

are also both applicable to show the relation. As a whole, of these three formulas the last agrees best with the result actually observed.

The humidity in the atmosphere has no considerable effect on the time of set either with or without an admixture. As a rule, however, the higher humidity tends to retard the time of set a little.

Any admixture retards the setting time in cement and lengthens the duration of setting generally. (Masao Hirano in *Memoirs of the College of Engineering, Kyoto Imperial University*, vol. 4, no. 5, Feb., 1927, pp. 261–340, 30 figs. on separate sheets, *eA*)

FUELS AND FIRING (See also Internal-Combustion Engineering: Carburetion of Kerosene; Pulverized-Lignite-Burning Plant in Texas; Special Processes: Automatic Gas-Pressure and Volume Control for Gas-Lift Producing Wells; Oil Recovery Under Artificial Pressure in the Seminole Oil Field)

A Comparison of Processes for the Cleaning of Coal

ALL modern coal-cleaning processes under proper working conditions can effect a satisfactory separation between "pure" coal and "pure" dirt. They vary, however, in their ability to deal accurately with interstratified particles of intermediate density. In selecting a process for cleaning coal it is frequently desirable to choose one which allows any predetermined proportion of the interstratified particles to be retained in the clean-coal fraction, the remainder passing into the refuse. The author does not think much of control of a washery on float-and-sink analysis of the cleaned coal and the refuse in liquid of some arbitrary specific gravity. He believes it is important to determine whether coal lost in the refuse consists of "pure" coal or of light middlings, for the loss of one per cent of pure coal may be more wasteful than the loss of three per cent of middlings.

The author gives the following classification of coal-cleaning processes:

- *A* Wet-cleaning process
  - *a* In which a current of water is employed
    - 1 A vertically upward current (the Draper washer)
    - 2 A current alternately upward and downward (the Baum washer)
    - 3 A current flowing over an inclined plane (The Rheolaveur washer; the Deister-Overstrom concentrating table)
  - *b* In which a medium of specific gravity greater than that of water is employed (the Chance process)
  - *c* Froth flotation processes (the Minerals Separation Co., Ltd., process)
- *B* Dry-cleaning processes
  - *a* In which a vertically upward current of air is used (the Wye separator)
  - *b* In which advantage is taken of the different coefficients of friction of coal and shale (spiral separators).

On theoretical grounds there is reason to suppose that in appliances employing a vertical upward current of air or of water it will be necessary to feed the raw coal in fractions carefully sized between certain limits. In practice it is found that at least with the two separators specially referred to by the author (Draper and Wye), the limits must be within the ratio of three to one. The necessity for sizing the coal does not exist in jig washers. For example, in the Baum washer, the water current is alternately upward and downward where the circumstances are such that the motion of the particles during the first instance of its motion is independent of its size. The same applies to some other washers referred to.

As regards froth flotation, this is limited to the cleaning of fine coal. In spiral separators, as the author claims, very close sizing of the particles is required.

On the whole the author believes that it is advantageous for a washer to be able to fulfil the following conditions: (1) There must be differentiation between light and heavy middlings; (2) there should be little mechanical stress on the particles; (3) the particles should be in contact with the water for a minimum time; (4) fine adjustments should be reduced to a minimum; (5) it should be possible to stop or start the plant rapidly, and efficient washing should obtain immediately on restarting; (6) there should be efficient operation with an irregular rate of feed and a feed varying in quality or size; (7) there should be a minimum number of accessory appliances, such as pumps, motors, elevators, conveyors, and screens. (First instalment of a paper read in July at the Coal Cleaning Conference held in Edinburgh under the joint auspices of the Coke Oven Managers' Association, the Institution of Gas Engineers, and the Fuel Section of the Society of Chemical Industry,

abstracted through *The Iron and Coal Trades Review*, vol. 115, no. 3097, July 8, 1927, pp. 43–44, *cp*)

Air-Swept Combination Ball and Tube Mills for Pulverizing Coal

DESCRIPTION of an American device made by the Kennedy-Van Saun Manufacturing and Engineering Corporation, New York. The combination mill in this case is an ordinary tube mill fitted with a partition forming two grinding chambers. The primary chamber is charged with large steel balls varying in diameter from 3 in. to 6 in., depending upon the size of the mill and the character of the coal. These heavy balls perform the initial breaking, the material being passed through a screen into the second compartment. This is charged with steel balls much smaller in size, varying from $^7/_8$ in. to 2 in. or $2^1/_2$ in. in diameter for the final grinding. The screen diaphragm is made of manganese steel and may be placed at any point. The final discharge from the mill is through a steel grate set back a short distance from the end. Between this grate and the discharge end of the mill are a number of radial blades which lift the pulverized coal and deliver it on to a cone on the mill axis, whence the coal is discharged through the trunnion.

An investigation of the work done in the long-tube mill has revealed the fact that the first foot of the mill does considerably more work than the second, and that in its first 4 ft. the mill has done as much work as the rest of the cylinder, when the length is from 22 to 28 ft. In these circumstances it was obvious that a large saving in power could be obtained if the coal could be removed from the mill as fast as it acquired the necessary degree of fineness.

The mills so fitted, i.e., the air-swept mills, are provided with boxes at either end, with valves on either side. The coal is fed to the mill by a disk feeder equipped with a cut-off, so that the quantity of coal fed to the mill may be increased or diminished without interfering with normal operation. The fan is attached to the air box at the discharge end of the mill, and the pulverized coal is drawn from the mill body and discharged into a bin or conveyor through cyclone separators. When the mill and fan are started, the amount of air put through the mill may be regulated by adjusting the valves at the feed and discharge ends.

There are no lifters in the mill and no coal is discharged except by air, so that the velocity of air through the mill regulates the degree of fineness to which the coal is pulverized. The velocity of the air through the mill is increased by opening the valves in the feed-box end and closing the valves in the discharging-end box.

In practice it has been found that, when using run-of-mine and slack coal, the pulverizer will dry the coal satisfactorily up to a moisture content of 10 per cent, and no drier need be used.

In one installation where this system is used, the boiler is of the vertical water-tube type, and is rated at 471 hp. The mill is 4 ft. by 8 ft., and pulverizes from 3000 to 5000 lb. of coal per hour, the power required being 20 hp. except when the pulverizer is started, when the load runs up to 100 hp. for about 30 sec. (*The Iron and Coal Trades Review*, vol. 114, no. 3094, June 17, 1927, p. 961, 1 fig., *d*)

HYDRAULIC ENGINEERING

Hydroelectric Plants of a Novel Sort

A FULLER utilization of water-power resources and a wider distribution of energy developed by hydroelectric plants were discussed in a document issued a few weeks ago by the League of Nations in connection with the International Economic Conference.

Therein attention is called to the practicability of rearing dams at high levels to form reservoirs into which water could be pumped by otherwise unemployed energy generated by power plants not at the moment working to capacity to meet load conditions. The purpose of thus using idle power resources would be to pump water to points where the accumulated water could be drawn upon at peak-load periods to generate energy that ordinarily is produced by reserve generating units that are called into service only intermittently and which represent large investments.

It is a well-known fact that power plants when working continously at capacity can produce energy at a much lower cost than is the case when the plants are operated at capacity only for a few hours out of every twenty-four. The object of using idle power to pump water to high reservoirs would be to create pools of potential energy, so to speak, that could be transformed into electric current for continuous distribution far and near to points requiring additional current when local demands at the pumping stations did not necessitate operating them to capacity. The idea is an ingenious one; and under some conditions it may be developed to advantage in a practical way. (Editorial in *Compressed Air Magazine*, vol. 32, no. 7, July, 1927, p. 2099, *d*)

INTERNAL-COMBUSTION ENGINEERING

The Supercharged Two-Stroke Cozette Engine

THIS engine is still in the process of development. It is of the double-piston, supercharged, two-stroke, two-crankshaft type. The most recent engine has its four cylinder barrels and its upper and lower crankcase in a central aluminum casting. The combustion chamber is formed by the heads of the opposed aluminum pistons and by the cylinder walls which are lined with cast iron elsewhere and not in the part forming the combustion chamber. The two crankshafts are connected at the rear by an intermediate spur pinion twice the diameter of the pinion on the main shaft. The pistons on the lower or exhaust camshaft uncover the exhaust ports on both sides of the engine. The upper or intake crankshaft uncovers the intake ports on one side of the cylinder only. The difficult problem with an engine of this type is the adequate cooling of the piston heads. While active water circulation can be maintained around the cylinder barrels, the two piston heads are subjected to intense heat and there is a tendency after a certain length of time for leaks to pass the rings into the crankcase. (The article does not give a full description of the construction of the engine.) (*The Autocar*, vol. 59, no. 1653, July 8, 1927, pp. 66, illustrated, *d*)

The Carburetion of Kerosene

THE WORK of the Bureau of Standards with aviation gasoline and that of Purdue University with motor gasoline (as constituted in 1919) furnish data for interpreting the carburetion requirements of fuels lying between the limits of volatility represented by these gasolines. In recent years the volatility of motor gasoline has decreased. Anticipating its trend toward kerosene as a limit, data on the carburetion of kerosene are here presented to provide additional information concerning the effect of fuel volatility on the carburetion problem, to show how an engine operating on kerosene reacts to variations in the strength and temperature of the mixture, to point out the optimum temperature for satisfactory performance, and to specify the correct mixture ratios for economy and for power.

Practically all of the data were obtained from a 280-cu. in., 4-cylinder stock engine, although a larger engine than the test engine was used to furnish certain supplementary information.

With inlet air preheated to 250 deg. fahr. (corresponding mixture temperatures 200 to 220 deg. fahr.) most distribution difficulties are eliminated. Under these conditions the correct mixtures for good performance and economical operation are as follows:

a At idling, a mixture of 0.0925 lb. of kerosene per pound of dry air. The required mixture then decreases in strength as the carburetor throttle is opened until half load is reached.

b For throttled operation above half load, the correct mixture is 0.0650 lb. of kerosene per pound of dry air.

c For high power with open-throttle operation, the correct mixture is 0.0900 lb. of kerosene per pound of dry air.

Detailed information regarding the effect of heat upon the various factors affecting engine operation are included. (Bulletin No. 27, Engineering Experiment Station, Purdue University, Lafayette, Ind. Abstracted from advance leaflet, *p*)

MACHINE PARTS AND DESIGN

The Bethlehem Torque Amplifier

A POWER steering device (Nieman patents) was developed by the Bethlehem Steel Co. primarily for the control of machinery and has since been reduced to proportions suitable for automobiles, through coöperation between Bethlehem and Stutz engineers.

The device comprises two small drums with gear teeth on the outer circumference, which are positively driven in opposite directions at a slow speed by means of a universal-jointed shaft from the engine. Inside of each drum there is a friction-lined expanding clutch band. One end of the band is anchored to an arm extending radially from the shaft carrying the steering worm, while the other is adapted to be moved away from the former and the clutch band thereby expanded and brought into driving contact with the drum by a radial arm extending from the shaft carrying the steering wheel.

The two clutches are so arranged that one will be engaged by right-hand and the other by left-hand rotation of the steering wheel.

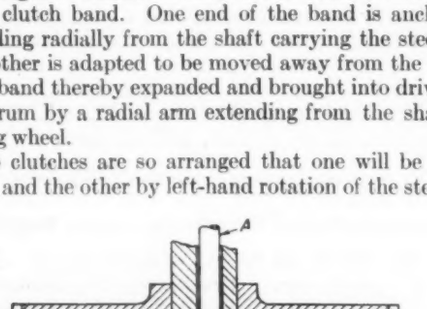

Fig. 2 Sectional Sketch of Nieman Power Steering Mechanism

(*A*, shaft or rod to which steering hand wheel is secured; *B* and *C*, clutch drums with gear teeth; *D* and *E*, clutch bands; *F*, arm on shaft *A* by which clutches are engaged; *G*, radial arm by which power is transmitted from clutches to worm shaft *H*.)

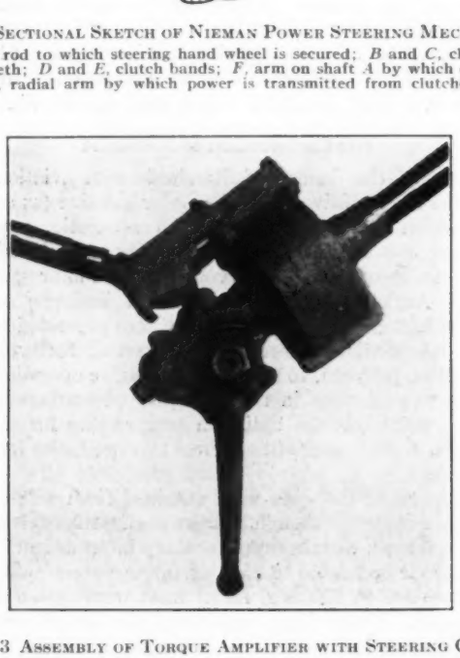

Fig. 3 Assembly of Torque Amplifier with Steering Gear

The motion is transmitted to the worm shaft by the radial arm carrying the clutch band. A small pivoted member serves as an automatic adjustment, compensating for wear, etc., so that the friction bands are always at the proper tension, and no backlash can develop. In external appearance the device is a small cylindrical casing on the steering column beneath the floor boards and immediately above the steering gear proper. From the driver's point of view the operation is in no way different from that of the ordinary car except for the extreme ease in steering. The "amplification" selected is ten to one, which means that with the same steering ratio as ordinarily employed the car steers with one-tenth of the usual manual effort.

In addition to this installation on the Stutz, a torque amplifier has been applied to a heavy truck, and the remarkable phenomenon is presented of a vehicle having a load of more than 6000 lb. on the front wheels being handled as easily and surely as a light passenger car.

Torque amplifiers have been designed for various purposes. One, working on the same principle as the steering control, is now under test for the rapid and precise pointing of anti-aircraft guns. The device is the invention of Henry W. Nieman, a Bethlehem Steel Co. engineer. (*Automotive Industries*, vol. 56, no. 23, June 11, 1927, pp. 896–897, 3 figs., *d*)

Cast-Steel Cable Chain

Because of interest of the British Admiralty in the subject, several firms have experimented on the problem of making cast-steel chains, and the Beardmore Foundry has produced a finished cast-steel chain which will pass the rigid test requirements laid down. The specification called for $12\frac{1}{2}$-fathom, 3-in., cast-steel, stud-link chain with the necessary shackle, and the original article gives the full data of the tests. The chain after passing the tests is at present in service and the result of its performance is awaited with interest. (*The Foundry Trade Journal*, vol. 35, no. 566, June 23, 1927, pp. 532, 1 fig., *d*)

MARINE ENGINEERING (See Steam Engineering: Uniflow Marine Engine with Oil-Operated Valve Gear)

MOTOR-CAR ENGINEERING (See also Machine Parts and Design: Bethlehem Torque Amplifier)

A Free-Wheeling Motor Car

For some time past tests have been made with a car to which a Humfrey-Sandberg free-wheel clutch has been fitted behind the gear box and the front end of the propeller shaft. This clutch is of a new type, and acts as a ratchet and pawl without the difficulties usually associated with the pawl.

When the car is running under its own power, and so long as the engine is pulling, the drive is normal, but the moment the engine ceases to pull—that is to say, when the driver lifts his foot from the throttle pedal—the special clutch behind the gear box frees itself and the car coasts, just as it does when running downhill with the gear lever in neutral. In other words, the engine can drive the car, but the car cannot drive the engine.

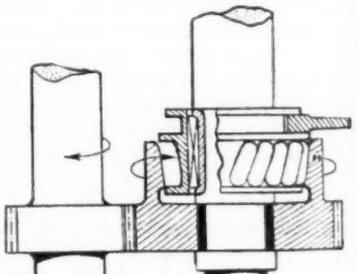

Fig. 4 Humfrey-Sandberg Clutch Making a Motor Car Free-Wheeling

The effect is exactly the same as when a cyclist "free-wheels," and it is a special claim that there is a considerable saving in gasoline because a car, normally, will run a considerable distance on the level without its engine power. There is, however, another advantage which is probably of far greater value. The moment the throttle is released the rear wheels cease to drive the gear-box shaft through the propeller shaft, and when the engine clutch is taken out no power is being delivered from the engine to the gear box, which thus is free at both ends, as it were. Normally, the rear wheels are still driving one of the gear-box shafts when the clutch is withdrawn.

This is said to be attained by the use of the Humfrey-Sandberg clutch (Fig. 4) similar to a roller bearing in which the roller path has a particular curved form. The curvature of the roller path on both the inner and outer clutch members is such that line contact is obtained for the rollers at a predetermined angle between the retaining flanges.

With the gears entirely free, gear changing becomes far easier, easier than when the car is standing still, and the so-called terrors of the gear change vanish for the novice. The expert, on the other hand, will find that a car fitted with this device is more difficult to handle than one with a normal gear box.

There is another important point affecting brakes. As long as the clutch is used for coasting, the speed of the car will have to be checked by the brakes and the brakes alone, whereas, in the ordinary

car, the very fact that the rear wheels are driving the engine through the gear box is a check on the car's speed of no mean value.

In the new device, however, it is possible to put the special clutch behind the gear box out of action, so that the car behaves in the normal manner and the engine overrun is used as a brake when descending steep hills. It may be interesting to recall that somewhere about 1905 or 1906 a car was tried with a ratchet and pawl free-wheel behind the gear box, and that this device ran very sweetly. In those days neither the ratchet nor the pawl stood up to the stresses imposed on them. It is the special type of Humfrey-Sandberg clutch which gives hope that the new device will be quite durable. (*The Autocar*, vol. 59, no. 1652, July 1, 1927, p. 13, 1 fig., *dA*)

PHYSICS

Surface-Solution or "Two-Dimensional" Fluid Layer

THE present article deals with the peculiar method of spreading of certain materials, such as oleic acid, benzoate of benzyl, camphor, etc., over the surface of water. The facts brought out in this discussion deserve the attention of mechanical engineers as they may possibly have something to do with certain phenomena occurring in boilers. The matter has been under investigation since the work of Lord Rayleigh in 1891, but it is only comparatively lately that the work of Duvaux, Marcelin, and others has made possible a fairly clear comprehension of the subject. From this it would appear that under certain conditions such materials as, for example, oleic acid, have the ability to spread upon the surface of water in a layer which to all practical purposes behaves like a gas in accordance with the Mariotte law, i.e., has the ability to spread indefinitely in two dimensions. It is this which led the author to call such a layer a "two-dimensional" layer, although this is, of course, not strictly correct mathematically.

A previous investigator of the subject, Duvaux, devised the following interesting experiment. Fine talcum powder was scattered over the surface of water and then a drop of oleic acid was carefully deposited on the water from the tip of a glass rod. The drop immediately began to spread, pushing the grains of talcum away, and if a black-bottomed dish was used for the experiment the difference between the color of the drop and the white wall of the talcum grains surrounding it gave a striking method of observing the spread of the oleic acid. After awhile the spreading of the drop ceased, which led at first to the supposition that the oleic acid formed a layer one molecule thick, and when such a layer was formed all further expansion stopped. It has since been found that this was not correct and that the cessation of spreading of the drop was due to the presence of the talcum powder.

Marcelin devised another test permitting not only the observations of the action of the expansion of the drop but the measurement of the forces developing therein. This was done by means of the "two-dimensional gun" shown at the left in Fig. 5. This "gun" is made up of a very thin paraffined sheet of mica, the "shell" being made of the same material. A small drop of oleic acid is deposited in what would correspond to the propellant charge chamber of the gun, whereupon the shell is immediately projected out of the gun, while the gun itself recoils backward, substantially as shown in the right-hand side of the picture. It is of interest to note that while oleic acid and camphor produce this effect, palmitic or stearic acids do not. The mechanism of action in this case may be explained in two ways, both, however, leading substantially to the same result. One explanation would be that the presence of the oleic acid in the gun chamber decreases the surface tension of the water, as a result of which the attraction on the shell produced by the water outside of the gun becomes sufficiently great to pull the shell out. The other explanation would be that the shell is propelled by the surface tension produced in back of it by the layer of oil.

Marcelin has devised an apparatus for measuring the surface pressure of a two-dimensional solution of this kind and worked out a formula giving its magnitude. His tests have shown that the expansion of the surface-solution layer may continue indefinitely under proper conditions. Among other things, he has shown by means of his apparatus that the variation of surface pressure with the area occupied by a given quantity of oleic acid follows exactly the Mariotte law for gases, the surface pressure being inversely proportional to the area occupied by the liquid, the limitations of this law being substantially similar to the limitations of the Mariotte law in that the law holds good only when the solution is sufficiently expanded, i.e., if it occupies initially a sufficiently large area, or, in other words, if its surface density is sufficiently small.

Delaplace studied the influence of temperature on the superficial solutions, using benzoate of benzyl as his material. He found that the product of the pressure by the area occupied varied directly with the absolute temperature within the range of temperature from 15 to 27 deg. cent., which would make it appear that a law similar to that of Gay-Lussac's for gases is applicable here.

Marcelin also investigated the irregular motions of a bit of camphor thrown into water and found that these motions are related to the formation of a surface solution, the average thickness of which is of the same order of magnitude as the computed diameter of camphor molecules, which is 0.6 millimicron. Marcelin even built a queer little camphor turbine. A bit of paraffined mica cut to proper shape, somewhat like a capital L, acts the part of a tuyere and is held stationary by three needles. At the mouth of the L is placed a little mica turbine wheel so arranged that it can freely rotate about a needle passing through its center. In the interior of the tuyere is placed a bit of camphor held stationary in contact with the water by a piece of wire. As soon as the camphor comes in contact with the water, the wheel begins to spin.

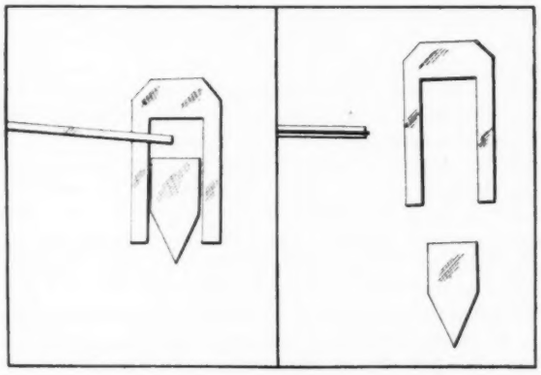

FIG. 5 MARCELIN TWO-DIMENSIONAL GUN

A number of other materials possess properties similar to those of oleic acid or camphor. Among the organic substances of this kind are menthol, citric acid, paratoluidin, and among inorganic substances bichromate of potassium, ferrous sulphate, cupric sulphate, ammonium chlorate, etc. (A. Troller in *La Nature*, no. 2761, May 15, 1927, pp. 443–448, 12 figs., *te*)

POWER-PLANT ENGINEERING (See also Steam Engineering: Economies of the Emmet Mercury Process)

The Cost of Steam

AN EDITORIAL in which an attempt is made to show how the cost of steam, say, 1000 lb., is calculated. To illustrate the point the writer takes a concrete case of an existing plant of, say, 600 hp. nominal rating, assuming that the plant will be operated 10 hr. per day, 300 days per year, with an average load of 400 hp. He calculates then the salaries of the help, the cost of fuel and water, fixed charges, and the various other factors entering into the cost of steam generation. While the figures given in the discussion are not typical, they are of interest both as showing the method of calculation and also as being somewhat representative of cost figures in many plants. (Editorial in *The National Engineer*, vol. 31, no. 7, July, 1927, pp. 331–333, *p*)

A Texas Plant Burning Pulverized Lignite

ONE of the interesting features of the Comal power plant recently completed at New Braunfels, Tex., is its ability to burn pulverized

lignite at high thermal efficiency. The plant represents very advanced design in other ways as it uses air preheaters, fin-tube water-cooled side and rear walls, floor water screens, and four stages of bleeder heaters for heating the feedwater. The boiler is designed for a steam pressure of 430 lb. per sq. in. gage to give 385 lb. per sq. in. gage and 700 deg. fahr. total temperature at the turbine throttle.

Being designed primarily to burn Texas lignite, a fuel which is more flocculent than coal when pulverized and which contains a large amount of moisture even after drying, the boilers and furnaces contain certain modifications which are of interest. The slag screens have been extended to comprise the first three rows of boiler tubes, the third, as well as the second, row of tubes used with standard spacings having been omitted to accomplish this. Also, the burner arches have been depressed below the boiler water legs farther than usual, so that the refractory walls above it are probably more than twice as high as those customarily used in pulverized-coal-burning furnaces. This has been considered advisable as a precaution against incomplete combustion that might otherwise occur at certain loads should the flocculency of the lignite give it a tendency to short-circuit the lower part of the combustion chamber. To accelerate combustion the primary air is preheated by passing through Detrick hollow walls, which are used in the ash hopper and also over the Detrick arch through which the burners project. The cooling effect of this air on these walls also reduces the cost of their maintenance. Secondary air for combustion is preheated, first by the plate-type air preheaters, then by hollow side walls through which it passes before entering the furnaces through the front walls. Each air preheater has 26,568 sq. ft. of effective surface and capacity for raising 85 per cent of the air required for combustion from an initial temperature of 100 deg. fahr. to an outlet temperature of 495 deg. fahr. when the boilers operate at 300 per cent of their rated capacity. The hollow side and front walls of the furnaces and the arches are of Detrick construction.

The fuel is crushed until all of it passes through a $^3/_8$-in. mesh screen. It is then delivered to the raw-fuel bins from which it goes through the driers to the pulverizing mills. The mill exhausters deliver the pulverized fuel to the cyclone separators, from which a system of duplicate screw conveyors distributes it to each of the two pulverized-fuel bins in front of the boilers, where a 24-hr. supply of pulverized fuel can be kept. Primary air at 250 deg. fahr. is introduced into the feeders which are located directly beneath the bins, and this air transports the fuel to the burners located at the level of the operating floor. Each boiler has 12 burners. The feeders have been arranged in two banks of six feeders each, which deliver the fuel to alternate burners. With this arrangement, if one group of six feeders is cut out of service the remaining group will distribute the fuel evenly across the width of the furnace.

Four stages of feedwater heaters designed for low terminal temperature difference between the steam and the feedwater—5 deg. at full load and approximately 3 deg. at the most economical load—the interposition of the after-condenser of the air ejector in the feedwater heating system between the first- and second-stage bleeder heaters, the use of bled steam for the evaporators and of a separate evaporator-condenser heater, and the separation of the heater draining system into distinct high-pressure and low-pressure systems, so designed that drains are independently returned to the feedwater with the minimum depreciation of temperature head practicable, are the principal points of interest in the plant's feedwater system. The fourth-stage feedwater heater and the low terminal-temperature differences were justified by the indicated resulting economies.

The matter of steam condensing was in this case a very simple one as a large quantity of water is supplied by springs at a temperature of 75 deg. fahr. throughout the year. With water at this low temperature continuously available a vacuum of 28.4 in. can be carried at the exhaust of the turbine under full-load operation without any circulating pumps. The quantity of spring water available is sufficient for a plant of 90,000-kw. capacity without recirculation. With recirculation the supply is ample for a station of 180,000-kw. capacity. (E. B. Severs, Engineer of Design, Electrical Department, The U.G.I. Contracting Co., Philadelphia, in *Manufacturers' Record*, vol. 90, no. 24, Dec., 16, 1926, pp. 79–86, *d*)

Water-Cooled Furnaces

Credit for originating and successfully applying water-cooled furnaces is given to Thomas E. Murray, the first water-cooled furnace having been installed on three of the boilers in the Hell Gate Station of the United Electric Light and Power Co. in New York.

The water-cooled furnace was a success from the beginning. The circulation through the side walls was perfect; efficiencies of 84.6 per cent on the boiler exclusive of economizer were attained and ratings up to 528 per cent were secured. Moreover the conditions of operation and maintenance proved to be quite favorable. When, however, it came to applying a water-cooled furnace to a powdered-fuel-fired boiler (Sherman Creek Station of the same company) considerable doubts were expressed due to the fear that the temperature would be so appreciably lowered as to prevent proper combustion of the powdered coal. It has been found since that the temperature in the water-cooled furnace may be continuously maintained at a higher value than in a refractory furnace and excess air may be decreased to a minimum value. The installation is said to have demonstrated beyond question the feasibility and success of the water-cooled furnace as applied to pulverized-fuel burning. Since then several other installations of the same character have been made.

The New York Edison Co. installed six Springfield horizontal boilers in its new East River Station. Each boiler proper contains 14,809 sq. ft. of heating surface and the water-cooled furnace contains 4134 sq. ft. The volume of the furnace is 15,888 cu. ft. Each boiler has a capacity of 250,000 lb. of steam per hour, 375 lb. pressure at a total temperature of 700 deg. The boilers are fired by the Lopulco standard down-firing method.

The New York Steam Corporation installed in the Kips Bay station three 10,670-sq. ft. Ladd boilers, the furnaces of which were provided with 4132 sq. ft. of additional water-cooled surface. These boilers operate at a normal capacity of 325,000 lb. of steam per hr. at a pressure of 275 lb. and no superheat. The furnace has a volume of 18,925 cu. ft. and is completely surrounded by the water-cooled surfaces. The coal is down-fired by means of the standard Lopulco system. These boilers are run normally at 700 per cent of rating based on the total surface of the boiler, water walls, and bottom screen. This is approximately 22 lb. of steam per sq. ft. of total surface. The surface exposed to the furnace in this case is about 35 per cent of the total surface.

A similar boiler and furnace, although of somewhat greater heating surface, is installed in the River Rouge Plant of the Ford Motor Co. at Detroit and has a capacity of 500,000 lb. of steam per hr.

The installations cited indicate clearly the effect upon boiler capacities of the water-cooled-furnace idea and the savings in space and building cost that are thus made possible. Applied to boilers now in operation the water-cooled furnace will help to solve, in a great many instances, the problems of industrial plants that are faced with increasing demands for steam at low capital outlays.

The success of the water-cooled furnace called attention to the matter of transference of heat by radiation. This has been studied in a paper by B. N. Broido on Radiation in Boiler Furnaces before The American Society of Mechanical Engineers, published in its Transactions, vol. 47, 1925, pp. 1123–1177, and the author bases his discussion on the figures presented in that paper. [Howard W. Leitch (Mem. A.S.M.E.) General Supt. of Power Plants, The United Electric Light and Power Co.; abstracted through *Power*, vol. 66, no. 4, July 26, 1927, pp. 129–132, 6 figs., *d*.] Compare also editorial in *Power* on p. 142, from which the following is quoted: "Opinion is still divided among engineers as to the relative merits of walls made up entirely of unprotected water tubes and those in which the tubes are protected by a thin layer of refractories. Both appear to be giving satisfaction, and the choice must be left to local conditions tempered by personal preference. It is significant that equipment manufacturers are now receiving many requests to figure on boiler installations to have capacities up to 350,000 lb. of steam per hour. Without the water-cooled furnace this would be impossible."

The Küma Grate

THIS grate belongs to the class of intensive-firing grates. Fig. 6 shows the general scheme of its operation. It is so arranged as to have a peculiar wave-like motion, this explaining also its name, as Küma means wave in Greek. Because of this motion the individual coal particles reach first the peak only to roll next into the trough. The forward motion of the fuel proceeds automatically and at a uniform rate without any assistance on the part of the fireman, and the velocity of advance of the coal, all other conditions being similar, depends only on the stroke of the device and the number of wave oscillations, both of which are adjustable within wide limits.

It is claimed that the mixture of the fuel with the air of combustion in this grate is an intimate one, as the air of combustion flows through the entire grate area in a multitude of fine streams and the relation of the parts is such as to produce a turbulent motion in the air, which is also of advantage.

The ashes are moved forward in the same way as the coal, and as they have to pass the entire length of the grate they have enough time for the complete combustion of the carbon contained. Moreover the ashes cannot adhere to the grate as this is in constant motion and the changes of position help to break off the clinkers from the grate. This is assisted by the cooling action of the draft which flows first along the side walls of the furnace, then passes under the grate, and finally comes back through the orifices in the nozzle plates. As a result the side walls and grate are kept cool, which prevents adhesion of clinkers.

It is stated that in about two years of operation of the grate there was scarcely a case when a nozzle plate had to be replaced because of wear or clogging by clinkers.

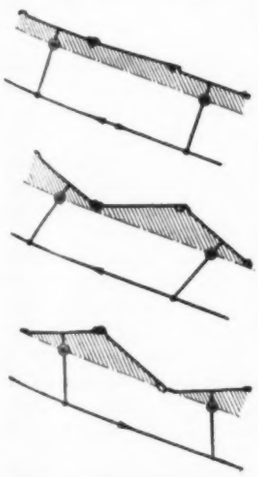

FIG. 6 DIAGRAMMATIC SCHEME OF THE KÜMA GRATE

After passing the entire length of the grate proper, the ashes and clinker finally reach the clinker grate, so arranged that it breaks the clinker, and located at the end of the grate proper. Here the preheated secondary air is admitted, assisting in the combustion of such fuel as may have been left, for which there is ample time, as the clinker grate is cleaned only once in a while by hand. Proper means are taken in the design of the installation so that during the process of slagging no excess air is admitted to the furnace. In larger installations means are provided for permitting the accumulation of a considerable amount of clinker through which hot air is allowed to pass. Automatic means are also provided for removing the clinker.

As in the combustion space there is only a slight draft of a few millimeters of water, the disturbances due to opening the doors or leakage in the brickwork are much less than with natural draft, which has to be considerably higher. Because of this the difference in efficiency under test conditions and in actual operation is said to be less in the case of the Küma grate than with hand firing.

The remainder of the article contains data of tests carried out on a Lancashire boiler and on a Stirling boiler. It is also stated that promising tests have been made with the same type of grate operating on a mixture of raw brown coal (practically lignite) with coke produced by the incomplete gasification of lignite. (Dr. of Engrg., Spindler in *Die Wärme*, vol. 50, no. 22, June 3, 1927, pp. 379–383, 9 figs., *de*)

Kisselbach High-Pressure Circulating Thermal Storage System

DESCRIPTION of a system designed to meet the need for a method of regulation that will take care of plant overloads and do so automatically. Fig. 7 shows in diagrammatic form this system applied to a water-tube boiler. The reservoir is simply an ordinary plain boiler drum. An existing boiler can be detached from the battery and converted into a storage reservoir, which would lessen the initial capacity outlay. The circulating pump is always in operation; its working capacity exceeds considerably the quantity of water absorbed for steam production at any time. The surplus water delivered into the boiler simply flows over and back into the storage reservoir. Both boiler and reservoir steam chambers are directly connected by equalizing pipes, thus equalizing the pressure throughout.

When the demand for steam is less than production, that is, on light load, the feed pump will deliver more water into the boilers than is absorbed for steam production. The surplus water becomes heated and absorbs the excess heat units made available while the plant is working on light load. The surplus water overflows into the storage reservoir, which is heavily lagged with asbestos or other heat-insulating material. When the demand for steam

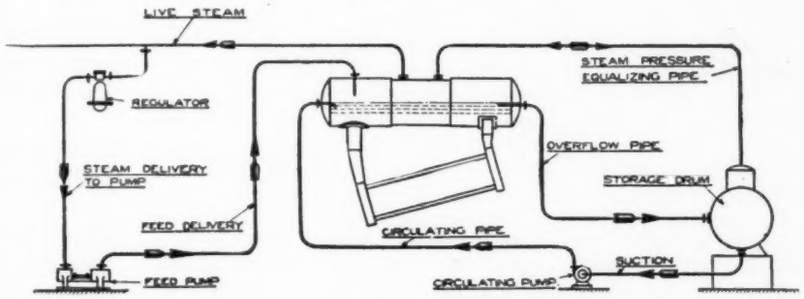

FIG. 7 DIAGRAM SHOWING THE KISSELBACH CIRCULATING THERMAL STORAGE SYSTEM APPLIED TO A WATER-TUBE BOILER

exceeds average requirements, the feed pump slows down, and may even become stationary, and during such periods hot water for steam production is taken from the storage reservoir. As this water from the storage is at high temperature, all the heat from the firing is made available for steam production. It follows, therefore, that the boilers are capable of yielding increased steam supply without suffering fall in pressure, notwithstanding the fact that firing continues at a constant rate.

A boiler plant equipped with the Kisselbach storage system requires no special control or regulation outside the apparatus, which automatically delivers water into the system proportionately to whatever quantities of steam are taken. In other words, the feed pump automatically responds to fluctuation in the steam pressure. If the load falls below the average, the pressure will rise, and the feed pump will be accelerated. On the other hand, when the load rises above the average the pump slows down or stops altogether. In the case of steam-driven pumps the regulator is inserted in the steam delivery pipe, but if the pump is driven electrically it is inserted on the water pipe on the pressure side. In both cases the regulation is entirely self-acting, no oil or water being required for it. The regulating apparatus is simple in design and construction; it will operate with variations in steam pressure from 1.5 to 3 lb. per sq. in. (*The Iron and Coal Trades Review*, vol. 114, no. 3093, June 10, 1927, p. 935, 2 figs., *d*)

RAILROAD ENGINEERING

Improving the Locomotive Boiler by Research

IT WAS only in 1904 when results from the Pennsylvania Locomotive Testing Plant at the St. Louis Exposition were published that the relation between overall boiler efficiency and rate of operation became fairly clear. From this and later tests it became possible to draw up complete heat balances for each locomotive tested. These balances separate the heat in the coal fired into five items, and the author tells how the various factors are determined, and the part played by the various sections of the boiler.

Among the things discussed is absorption of heat by radiation. Examination of a number of locomotive-boiler tests leads to the belief that the heat transfer in the firebox is governed by a law approaching the Stefan-Boltzmann law for radiation, although it seems necessary to introduce a corrective factor to bring into account the fact that at low rates of combustion the incandescent

body of gas does not fill the firebox as completely as it does at the high rates.

It is believed that further study will give a reliable rule for the rate of transfer of heat in the firebox. This is important as providing a correct method for determining the evaporative value of firebox heating surface. Consideration of the data on which the foregoing conclusions are based indicates that the evaporative value of firebox heating surface depends on the firebox temperature, which in turn depends on the relation between rate of heat production, weight of gases of combustion, and area of firebox heating surface.

With a given rate of heat production and a given weight of gases the firebox temperature must be such that the heat radiated at that temperature together with the heat carried by the gases at that temperature is just equal to the heat produced. An increase in firebox heating surface would throw matters out of balance unless the firebox temperature were reduced. The original temperature would maintain the rate of radiation unchanged so that the increase in firebox surface would increase the total heat radiated. Since the amount of gas-carried heat, which is dependent on the temperature, would not change, the total heat taken out of the firebox would be increased without an increase in the heat produced which is, of course, impossible. To maintain a balance an increase in firebox surface must be accompanied by a drop in temperature, thus lowering the amount of gas-carried heat. The lower temperature will give a lower rate of radiation per square foot, so that though the total heat radiated will be greater with the greater surface, the increase in heat radiated will not be in proportion to the increase in firebox surface.

Information available at present allows the foregoing statements to be made with confidence, but knowledge of this important subject is by no means complete and research would undoubtedly produce valuable results.

A formula has been developed for estimating the transfer of heat by gas convection. This formula shows that the temperature drop along the flue depends on the temperature of gas and of flue, on the flue dimensions, and on the rate of gas flow in the flue. This formula will give a high degree of accuracy, provided the method of determining or estimating the flue-wall temperature is right. The author further shows that doubling the rate of gas flow with the same surface of the flue very nearly doubles the total amount of heat transferred from the gas to the flue. This he considers an extremely important proposition. Among other things it shows that if half the tubes in a locomotive boiler were plugged and if it were possible to maintain the same total amount of gas flow as before, the doubled rate of flow in the remaining flues would increase the activity of heat transmission to such an extent that the evaporative power of the boiler would be reduced by only about four per cent. It becomes evident, therefore, that the major factor in determining the evaporative power of the flues is not the area of heating surface they offer, but the amount of gas that can be taken through them. In an actual locomotive boiler working at high power it would not be practicable to plug half the tubes and still maintain the same total rate of gas flow. The increase in draft required to move the same amount of gas through half the number of flues would be prohibitive. It is, however, a matter of fairly common experience that a considerable number of flues can be blocked up without reducing the capacity at all proportionately. Applied to the superheater flues the same formulas show similar curves, but with a slightly more rapid drop of temperature. This would indicate that the gases emerging from the superheater flues would have a slightly lower temperature than the gases from the plain flues. In view of the higher steam temperature in the superheater pipes this is not exactly what might have been expected, but there is some experimental evidence in its support.

The formulas as at present established are of value in showing how heat transfer by convection is affected by the various factors—rate of gas flow, temperature, diameter, and length of flue. To apply them though, at present, it is necessary to make certain assumptions as to the relative distribution of gas between the superheater and the plain flues, and also as to the wall temperature of the flues. Further research to throw more light on these points would make the formulas of still greater value in analyzing locomotive-boiler design.

The temperature drop is given by the equation: lolog $(T_1/t) - Mx =$ lolog (T_2/t), where "lolog" means logarithm of the logarithm of a number; T_1 is the absolute gas temperature at any point, and T_2 is the absolute gas temperature at a point x feet along the flue; M is a coefficient depending on the flue diameter and rate of gas flow in accordance with the following equations: $\log M = B - m \log W/P$; $\log (B + 1.3) = 9.71 - 0.54 \log d$; $\log m = 9.36 + 0.37 \log d$; where W is the weight of gas in pounds flowing per hour through the flue; P is the inside perimeter of the flue in inches; d is the inside diameter of the flue in inches. [Lawford H. Fry (Mem. A.S.M.E.), Metallurgical Engr., Standard Steel Works Co., in a paper before the Montreal convention of the Mechanical Division of the American Railway Association, June 7–10, 1927; abstracted through *Railway Mechanical Engineer*, vol. 101, no. 7, July, 1927, pp. 407–410, 4A]

REFRIGERATION (See Air Engineering: Refrigerating Turbo Compressor for 6,000,000 Kilo-Calories per Hour)

RESEARCH (See Railroad Engineering: Improving the Locomotive Boiler by Research)

SPECIAL MACHINERY (See Fuels and Firing: Air-Swept Combination Ball and Tube Mills for Pulverizing Coal)

SPECIAL PROCESSES

Automatic Gas-Pressure and Volume Control for Gas-Lift Producing Wells

THE USE of the gas-lift system in oil fields is described in the preceding article by Robt. G. Skerrett. The opinion generally prevails among production engineers that in this method it is desirable to maintain a constant delivery of gas into any given well. This creates a need for a device which in addition to accomplishing the regularity of flow will give a varying regularity with variations in direct proportion to and as a result of the naturally low-pressure fluctuations. Such a device, called the Thomas gas-lift control, is described and illustrated in the present article. It is claimed that this control will regulate the feed of gas so that when a lesser pressure is required the gas will be fed under a correspondingly lesser pressure and volume and the pressure and volume will properly increase when a higher pressure becomes necessary. It is also claimed that the action of the entire system is capable of adjustment to suit varying conditions. (J. V. Thomas in *Oil Field Engineering*, vol. 2, no. 3, July 19, 1927, pp. 35–37, 5 figs., *d*)

Oil Recovery Under Artificial Pressure in the Seminole Oil Field

AFTER mining petroleum by substantially unchanged methods for more than half a century, the producer has recently called to his aid new agencies that bid fair to add tremendously to the ultimate yield of underground sources of oil. Among other things it has been found that the use of compressed air or natural gas can be utilized to conserve or to supplement rock pressure, and thus induce a more prolonged or more copious flow of the oil through the sand to the well. The present article describes this practice in the Seminole field.

The conditions in the Seminole field for the application of this process were very severe. The wells are of great depth, while the rock or gas pressure is relatively low, necessitating very careful handling of the compressors in order not to set up back pressures that would reduce or possibly obstruct the further natural flow of the oil through the sand to the wells.

The general practice in the oil industry in the United States has been to permit the oil well to flow of its own accord as long as the gas pressure in the formation sufficed to bring the oil to the surface, and when this movement ceased, to begin pumping or swabbing in order to continue the recovery of the petroleum. This procedure has not been followed in the majority of wells in the Seminole field. There a compressor was brought into play

at an earlier stage so as to prolong the natural flowing period, some of the wells being actually hooked up with the compressor almost from the very beginning of the operation. The process employed is an adaptation of the air-lift principle.

The well equipment consists fundamentally of two tubes or pipes—one within the other, with compressed air being released into one of these tubes near the bottom. The rising and expanding air produces a lighter column of combined air and water which is lifted to the surface of the ground by the greater weight of the counteracting solid column of water. One of the operative advantages of the air lift is that there are no moving mechanical parts in the well to become inefficient by reason of wear or corrosion. Manifestly, both air and water are discharged at the outlet end of the lift. Similarly, the oil reaches the top of the well; and, in certain cases, in the form of a spray.

At some wells, natural gas instead of air is compressed by the compressors and utilized to operate the lifts in the Seminole field. The reasons for using gas are: Gas is from 3 to 4 times more soluble in oil than air under identical pressure; and the gas lowers the viscosity of the oil so that it will flow more freely through the containing sand, while air tends to increase the viscosity of the oil and, therefore, may impede the flow of oil. Furthermore, the gas is effective in absorbing gasoline in the oil—making possible a higher recovery of gasoline from the gas issuing from the gas lift. Air would lessen or dilute the gasoline content and, in the presence of water, would induce the rapid corrosion of the well casing and the smaller tubing enveloped by that casing.

When gas is employed, the gas lift is operated as a closed cycle—the gas being used over and over, like a continuous belt, to bring the oil to the surface and to promote the recovery of gasoline. However, some companies utilize air in preference to gas because of the greater lifting power of the air, and consequently obtain a higher production of oil from a given volume of input of compressed air. The explanation of this is that a low percentage of the air is taken into solution by the oil and, by reason of this, more air is immediately available to help in lifting the petroleum surfaceward.

In a general way, the function of the air lift as applied to the oil well is to circulate a gaseous medium—either natural gas or air—in a well so as to raise the oil that has reached the well. The next step is to extract the gasoline from the gaseous medium that lifted the oil; then, after this treatment, the gaseous medium is recompressed; and, finally, the compressed dry gas is reintroduced into the well to continue the operating cycle. In this way, not only is the flowing period of the well prolonged considerably beyond that that would take place if only natural pressure were relied upon, but the introduced compressed dry gas is highly effective in increasing the total volume of recovered gasoline.

The original article gives some further details as to the application of this process. To meet the unusual conditions of operation, compressors have been developed especially for service in oil fields in connection with gas- or air-lift pumping equipment. One type is available which is capable of providing a starting pressure of 1000 lb. and of maintaining a continuous working pressure of 500 lb. (Robt. G. Skerrett in *Compressed Air Magazine*, vol. 32, no. 7, July, 1927, pp. 2067–2076, illustrated, *dA*)

STEAM ENGINEERING

Economies of the Emmet Mercury Process

A DESCRIPTION of the Emmet mercury process was published in MECHANICAL ENGINEERING, vol. 46, no. 2, February, 1924, pp. 91–93. In this process mercury is evaporated in a special boiler and condensed after passing through a turbine in a condenser. Because of the high temperature of evaporation of mercury, the mercury condenser operates at such a temperature that it produces steam from the cooling water. A unit of that type was installed some years ago at a central station in Hartford, Conn. A 10,000-kw. unit is now being built and the following table gives the data as to designed conditions. It is claimed that its substantial accuracy is fully established by experience with apparatus now operating.

Output of mercury turbine, kw.	10,000
Speed of mercury turbine, r.p.m.	720
Steam produced, lb. per hr.	125,000
Steam pressure, lb. per sq. in. gage	350
Steam temperature, deg. fahr.	700
Mercury vaporized, lb. per hr.	1,150,000
Temperature of mercury vapor, deg. fahr.	884
Pressure of vapor at mercury turbine, lb. per sq. in. gage	70
Vacuum in mercury condenser, in. of Hg	28
Temperature of mercury exhaust, deg. fahr.	458
Gas temp. beyond mercury liquid heater, deg. fahr.	950
Gas temp. beyond steam superheater, deg. fahr.	650
Gas temp. beyond water economizer, deg. fahr.	480
Gas temp. to stack, deg. fahr.	280
Air temp. entering furnace, deg. fahr.	390
Coal burned, lb. per hr.	14,500
Heat in coal, B.t.u. per lb.	14,500

With the knowledge that such results can be produced, it is easy to calculate what effect the use of such a method of steam generation will have in any type of plant, or what its partial or complete substitution for steam boilers will accomplish in any existing case. Exact calculations of such economies, however, will require much study of detail in each specific case; but a general idea of the possibilities can be obtained from the following figures which give approximately the fuel economies that can be attained with the mercury process in combination with apparatus of different types in existing steam plants.

FUEL RATES IN B.T.U. PER KW-HR.

	Steam alone	Steam with mercury	Per cent gain
Case A	14,000	9,400	50
Case B	17,000	10,400	64
Case C	22,000	11,600	90
Case D	35,000	13,800	150

Case A represents the best development of modern plants with 350-lb. pressure, high superheat, and the most effective auxiliary and feed-heating arrangements.

Case B represents a station that was considered very good a short time ago with about 200 lb. steam pressure, less perfect firing and auxiliary arrangements, and less superheat.

Case C represents a station in which conditions of size, load factor, or efficiency are even less favorable.

Case D represents what might be done in a good non-condensing station.

The ratios here shown are not much affected by the usual causes of relative inefficiency such as load factor, turbine efficiency, or condensing facilities.

It is expected that generally the application of the process will give the largest returns for the investment as an addition to existing plants. Even when the cost of the additional installation is high, the addition should be desirable, because the increased output is obtained at the remarkably low fuel rate of about 4000 B.t.u. per kw-hr. added. The original article shows also the application of this method to a heating plant, such as a city heating plant, where it is claimed power can be produced at a fuel rate of about 16,000 B.t.u. per kw-hr., 100 lb. of heating steam being produced in addition. (W. L. R. Emmet in *General Electric Review*, vol. 30, no. 7, July, 1927, pp. 339–341, 2 figs., *d*)

A Uniflow Marine Engine with Oil-Operated Valve Gear

DESCRIPTION of a marine steam engine recently built by Sulzer Bros. for the passenger steamer *Helvétie* for service on Lake Geneva. The engine shown in Fig. 8 is a three-cylinder uniflow unit developing 1500 b.hp. at 46 to 50 r.p.m. and giving the vessel a speed of 15.25 to 16.75 knots. The valve gear represents a complete departure from ordinary practice, the usual mechanical gear with eccentrics, rods, and links being replaced by an oil-operated gear. Central, forced lubrication is used.

The three cylinders are carried by a central casting which serves also as an exhaust-steam reservoir, the exhaust steam passing from it to the condenser by means of two short pipe bends. The body of each cylinder is composed of two parts bolted by flanges to the central casting. The adjacent ends of these parts (Fig. 9) do not meet but have an opening between them which serves as a central exhaust port for the cylinder. In order that the piston and rings may pass over this port without difficulty, the ends of the half cylinders which form the sides of the port are made of a wave form, the crests of one piece entering the hollows of the other so that the piston rings are perfectly supported as they cross the opening. The construction of the cylinder in two parts not only allows an unobstructed port opening round the whole of the circumference with consequently the minimum width of port, but also does much to eliminate dangerous heat stresses.

The design of the stuffing box is shown in an illustration in the original article. A complete double metallic packing is fitted to keep each piston rod steam and vacuum tight. The inner packing, which serves to keep the rod tight against steam pressure, is pressed outward against the spherical seat, both by the steam and by very small axial springs. The packings are similar, each consisting of two rings of four packing segments pressed against the rod by radial springs.

The length of the piston is about 90 per cent of that of the stroke. The piston consists of two piston heads, a central piece and a slipper. The steam pressure is transmitted by one or the other of the piston heads directly to the rod. The weight of the whole piston and rod is carried by the slipper. The latter is provided with a spherical cup-shaped socket in which the central piece rests, and which provides sufficient flexibility to avoid possible strains and distortions due to heat. The crosshead has a spherical joint connecting it to the slipper, the reason for its installation being to insure uniform stressing of material and allow the parts to accommodate themselves to changes of form or of alignment caused by working stresses or heat or straining of the ship's hull during rough weather.

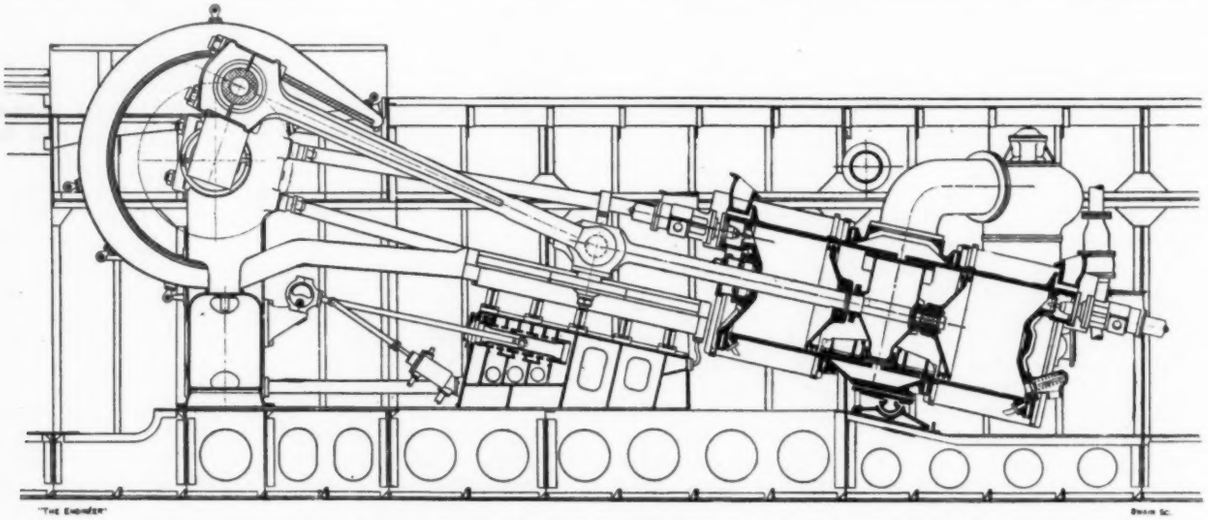

FIG. 8 LONGITUDINAL SECTION THROUGH ONE CYLINDER OF THE SULZER UNIFLOW MARINE ENGINE

The big ends of the connecting rods are of the standard marine pattern. Advantages of a spherical bearing have been made use of by providing the nuts and bolt heads with spherical working faces bearing on spherical washers. The bodies of the bolts are also turned down so that their cross-section is approximately equal to that at the root of the threads. By these precautions it is made as certain as possible that the connecting-rod bolts are uniformly and centrally stressed, thus reducing the chances of breakage to a minimum.

The paddle-wheel bearings are located outside the hull on special supports, and the novelty of forced lubrication has also been applied to them. A new method of construction is the supporting of the bearing body on two spherical pads, in order to allow for unavoidable changes in shape of the hull and to insure the shaft resting uniformly on the bearing surfaces. Since at every speed the forces working on the paddles, together with the weight of the paddle wheel, give a resultant force acting in direction between the two supporting pads and directed downward, the upper cap cannot be designed to bear on the shaft but serves only as a protection against the entry of dirt; for this reason also only the bottom shell of the bearing is lined with white metal. Here also lubricating oil is supplied from the central forced lubricating system of the engine, being introduced in the middle of the bearing through a ring groove, while the pipes which conduct the oil back to the general oil piping, are arranged at both ends.

The principal advantage of the oil-operated valve gear lies in the possibility of reducing considerably the dimensions of the engine and also of being able to arrange the valves in any desired position.

One of the steam admission valves, with its operating gear, is illustrated in Fig. 10. The valve itself is of the single-seated mushroom type, and is actuated by oil under pressure. The forces tending to close the valve are the steam pressure on the back of the valve V and the pressure of the spring F. The forces tending to open the valve are the oil pressure from the pipe O acting on the underside of the piston K in the oil cylinder M, and steam pressure in the cylinder Z acting on the underside of the valve V. The valve begins to open only when the compression pressure in the cylinder has reached its maximum value, since the oil pressure alone is not sufficient to open the valve against the steam pressure on its back. The oil control valve, which is shown in Fig. 11, has therefore, during the normal running of the engine, only to operate the closing of the valve V when cut-off takes place, as the opening of this latter valve on the return stroke of the piston is determined by the compression in the cylinder. When the engine is starting the compression pressure is too small to open the valve against the steam pressure. In order that the engine may be capable of starting, it is necessary to reduce the admission steam pressure until the pressure of the oil alone is sufficient to open the admission valve. As soon, however, as the engine has made a few revolutions, the steam pressure can be raised to full boiler pressure. To cause the valve to return quietly to its seat when closing and to come to rest without shock when opening, the motion of the piston K, shown in Fig. 10, is arranged to close one after another a series of holes drilled helically through the walls of the cylinder M. The piston thus acts as an oil brake, and it brings the valve definitely to rest when finally a certain quantity of oil is trapped by it in the cylinder. In order to make the braking piston conform exactly with the closing position of the valve, the cylinder M (Fig. 10) can be moved axially by means of the screw S, the worm wheel C, and the thread G, thus obtaining very smooth motion of the valve. During opening and closing, the oil enters at first through the foot valves W_1 and W_2, until a sufficient number of the helically arranged holes through the piston have been uncovered.

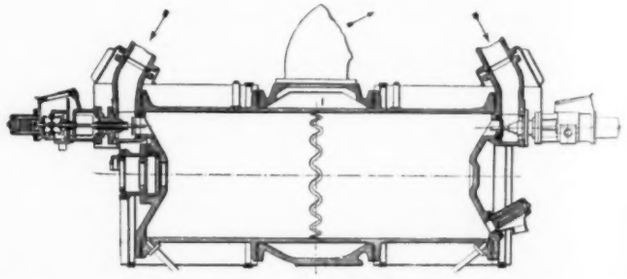

FIG. 9 LONGITUDINAL SECTION THROUGH ONE OF THE CYLINDERS OF THE ENGINE SHOWN IN FIG. 8, SHOWING CONSTRUCTION OF THE CYLINDER

The operating oil, which is brought to the requisite pressure by means of a special auxiliary pump, flows first of all into the space A

of the valve chest K (Fig. 11) to which two oil-storage vessels are connected in order to prevent the pressure varying too much. From the storage space A the oil passes into the annular space R_1 and is from here directed alternately into the annular spaces R_2 and R_3 according to the position of the control valve. The oil flows away from both spaces over the control valve into the spaces R_4 and R_5, which are connected with the damping spaces P_1 and P_2, respectively. To each of the latter spaces an oil damping device is connected. After the valves have completely closed, this device acts as a quick brake on the oil columns in the pipes O_1 and O_2, so as to prevent liquid hammer. In order to prevent the columns being broken during the braking operation, an oil make-up valve U is fitted in the valve yoke, Fig. 10, and feeds oil at once to the

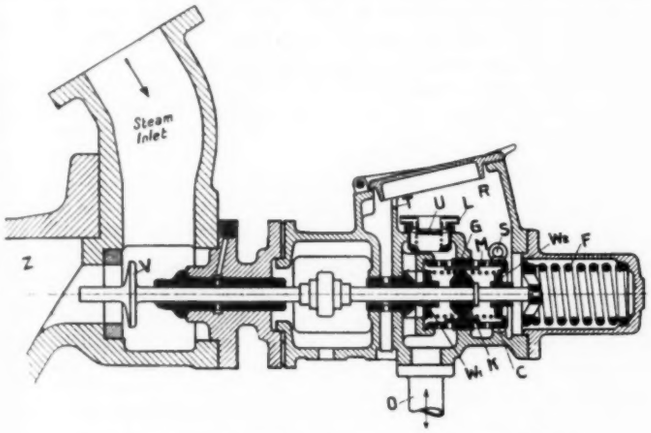

FIG. 10 STEAM ADMISSION VALVE AND OPERATING GEAR

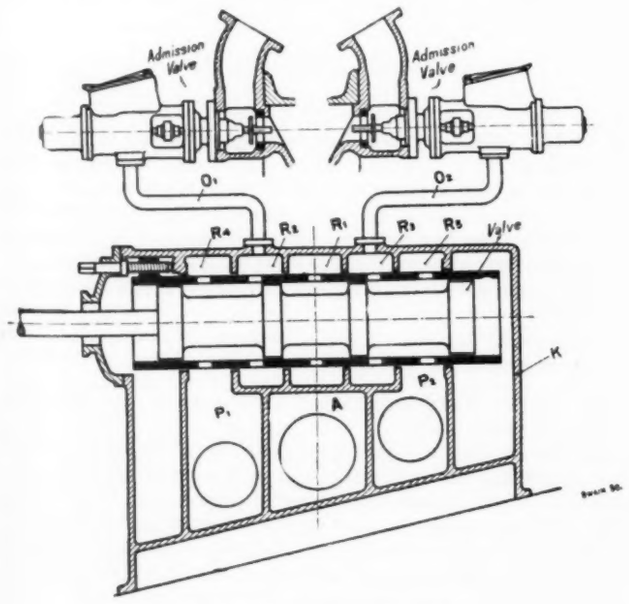

FIG. 11 OIL CONTROL VALVE

columns as soon as any vacuum forms. During the period the valve V is opening, when there is pressure under the piston K, the make-up oil contained in the space R can be replenished again through the holes L and any surplus can reach the drain pipe by the overflow T.

The operating valve is driven by an eccentric, and the angle of lead can be adjusted as required by means of a four-wheeled mechanism described and illustrated in the original article. The main steam valve is opened and closed by the operating lever of the service gear through an oil-operated mechanism with servomotor and control valve. The engine can only start with low pressure and large cut-off, and the cam of the control gear is suitably adjusted. By the single operating lever of the service mechanism, the main steam valve and the reversing gear are adjusted simultaneously by one easy movement, and without any exertion on the part of the engineer. Incorporating two difficult operations in one easy movement means quick maneuvering, an advantage by no means to be underestimated on board ship. (*The Engineer*, vol. 143, no. 3728, June 24, 1927, pp. 676–679, 13 figs. For a more complete account see Sulzer, *Technical Review*, no. 2, 1927, pp. 1–7, 14 figs., *dA*)

TESTING AND MEASUREMENTS

New French Units of Pressure and Force

IN THE past, side by side with the C.G.S. units, certain commercial units were employed in engineering works in France. The units for these were the meter for length, the second for time, and the kilogram-weight for force. Accordingly, the unit of mass was $M = P/g$ where g is the acceleration due to gravity, equal to 9.81 in Paris. The unit of pressure was a kilogram per square centimeter; the unit of work, a kilogram-meter; the unit of power a horsepower equal to 75 kg-m. per sec. This particular system had a disadvantage from a scientific point of view in that the fundamental unit of force represented by the attraction due to gravity on the standard kilogram varied with altitude and also with latitude. As a result it became necessary to define the place and altitude for which the weight of a kilogram was exactly equal to the unit of force.

It is because of this that the French law of April 2, 1919, instituted a new system, M.T.S., in which the fundamental units are for the length, meter; for mass, ton; and for time, second. It is very important not to confuse this ton-mass which is the same at all points of the earth with the ton-weight, which varies in accordance with the geographic location.

In this system a unit of force which was formerly based on the kilogram-weight has been made entirely independent of gravity and is now defined as a force which in a second imparts to a mass equal to one ton an acceleration equal to one meter per second per second. This unit is called a "sthene."

$$1 \text{ sthene} = 1 \text{ ton-mass} \times 1 \text{ m. per sec. per sec.}$$

Furthermore

$$1 \text{ kg-mass} = \frac{1 \text{ kg-weight}}{9.81}$$

$$\text{and } 1 \text{ sthene} = \frac{1000 \text{ kg-weight}}{9.81} = 102 \text{ kg-weight.}$$

This is the value in Paris; at the pole a sthene would have a value of 101.9 kg-weight, and at the equator, 102.2.

In the new system the unit of pressure is called a "pieze" and is defined as a uniform pressure which, when distributed over a surface of 1 sq. m., produces an effort equal to 1 sthene. Hence

$$1 \text{ pieze} = \frac{1 \text{ sthene}}{1 \text{ sq. m.}} = 102 \text{ kg-weight per sq. m.}$$

Where this unit is either too small or too large for practical purposes, multiples and submultiples may be used (designated in the same manner as other metric units). Thus, to express steam pressures, the hectopieze (hpz.) may be used. It is equal to 100 piezes or 10,200 per sq. m. or 1.02 kg-weight per sq. cm.

The hectopieze is therefore about 2 per cent larger than the old unit, and to pass from one to the other it is necessary to use 0.981 as a multiplier or divisor.

The hectopieze is from now on a legal unit of pressure in France, but it is expected that for many years to come the old units will be tolerated, particularly as France is the only country which has adopted these units. (V. K. in *Bulletin des Associations Francaises de Propriétaires d'Appareils a Vapeur*, vol. 8, no. 27, Jan., 1927, pp. 73–75, *dp*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are:

ARCHIBALD BLACK,
Aeronautic Division
H. W. BROOKS,
Fuels Division
R. L. DAUGHERTY
Hydraulic Division
JAMES A. HALL,
Machine-Shop Practice Division
CHARLES W. BEESE,
Management Division
G. E. HAGEMANN,
Materials Handling Division
J. L. WALSH,
National Defense Division
L. H. MORRISON,
Oil and Gas Power Division
W. R. ECKERT,
Petroleum Division
F. M. GIBSON and W. M. KEENAN,
Power Division
WINFIELD S. HUSON,
Printing Machinery Division
MARION B. RICHARDSON,
Railroad Division
JAMES W. COX, JR.,
Textile Division
WM. BRAID WHITE,
Wood Industries Division

Fuels

Stacks for Oil Burners[1]

F-18 A heating boiler with a rating of 6400 sq. ft. of radiation surface requires, according to the makers, a stack 20 in. by 20 in. by 60 ft. This rating is based on the use of free-burning coal (either hard or soft). In transferring to oil as fuel, what changes must be made in the flue dimensions to obtain best results?

There have been many and varied opinions on the subject of flues for oil-burning equipment employing mechanical-draft burners.

Boiler manufacturers make the flues of boilers a little oversized, so naturally when a mechanical-draft burner is installed this size may be decreased slightly; but some oil-burner distributers and dealers have gone to the extreme of informing prospective purchasers that an oil burner may be operated practically without a flue.

The height of a chimney or flue does not have a direct bearing on a mechanical-draft burner, because the gases are driven out by the air that is forced into the boiler to complete combustion of the oil, but the diameter of the chimney must be large enough to release the gases generated in the furnace.

Approximately 225 cu. ft. of air is required to burn one pound of oil, therefore, if in burning an amount of oil sufficient to meet the radiation capacity of the boiler mentioned there is generated a greater amount of gases than can pass out of the flue, an odor of oil gases in the cellar and house will be the result. Often when starting a burner under these conditions the dampers and doors are caused to vibrate.

One can readily account for the opinion that an oil burner needs practically no flue, because a mechanical-draft oil burner can be made to operate while exhausting directly into the air. But if the boiler is connected to a flue that is too small to accommodate the gases that are generated by the burner, it can readily be seen that there will be a back pressure of considerable proportions.

The writer recalls an interesting case in St. Louis where a boiler was installed in an old building and attached to a 6-in. by 6-in. flue. Two distributers had said that their burners would function properly with this size of flue, while the boiler manufacturer called for a 12-in. by 16-in. flue. The writer's contention was that the burner would not function with such a small flue, that the furnace would fill up with gases, the doors would vibrate, and the back pressure would smother the fire. After considerable deliberation the burner was installed with no alterations in the flue. When the installation was tested the burner functioned beautifully for a time. Soon, however, the furnace filled with gases, the firedoors trembled, and the flame fluctuated badly. The purchaser was quickly convinced that a larger flue should be built. Today, with a 12-in. by 12-in. flue the burner is functioning perfectly.

The dimensions advocated by the writer for the average household job, which does not require an engineer for layout, are as follows:

Up to a 20-in. grate, an 8-in. by 8-in. flue
From a 20- to 28-in. grate, an 8-in. by 12-in. flue.
Form a 28- to 34-in. grate, a 12-in. by a 12-in. flue.

The writer has found that if there is a sufficient number of sections in the average boiler, whether round or sectional, to permit a long travel of the gases, so that the heat will be extracted into the boiler before reaching the flue, a low stack temperature and efficient boiler will be the result. Round boilers have been altered by inserting several intermediate sections when oil burners were installed, with the result that efficiency has been increased 30 per cent. However, these additional sections would not result in good boiler operation with coal as a fuel. (William C. Groff, President Kleen Heet Co., St. Louis, Mo.)

Machine-Shop Practice

Gear Combinations

MS-14 In a combination of high-speed gears having a center distance of $14\frac{1}{2}$ in., a face width of 10 in., a tooth pressure of 320 lb. per sq. in., a ratio of approximately 5.7, a pressure angle of 20 deg. in diametral plane, and a tooth speed of 6000 ft. per min., which of the following combinations will produce the more quiet operation? (*a*) D.P. = $^6/_8$, number of teeth in contact, approx. 1.25, helix angle = $22\frac{1}{2}$ deg., cut on a gear shaper; (*b*) D.P. = 8, number of teeth in contact, approx. 1.67, helix angle = 35 deg., cut on a gear hobber. What are the factors which govern the decision in the above cases?

This question introduces several factors which the writer will try to treat individually.

Duration of Contact. For spur gears the duration of contact must not be less than one pitch interval if a smooth flow of power is to be secured. Additional contact is necessary to help to compensate for any errors that may be present—the greater the errors, the greater the overlap should be. In practice, it seems to be desirable to have the duration of contact not less than 1.4 tooth intervals in ordinary commercial gears. A lesser contact than this is sufficient when the order of accuracy is high. This excess contact enables slight modifications to be made in the tooth form to compensate for spacing errors. Needless to say, the greater the distance in which a given error is adjusted, the less the shock of such adjustment. With helical gears, however, the tooth-profile contact is of secondary importance, as the motion will be transmitted along the helix even if the tooth-profile contact is less than one tooth interval. Here an increase in tooth-profile contact increases the length of the actual contact line slightly, and thus would increase its load-carrying ability accordingly.

Helix Angle. The choice of a helix angle depends upon several factors. First, it is usually desirable to have as many teeth in contact across the face of the gear as possible, because this multiple contact tends to integrate the spacing errors and is thus conducive to more quiet operation. On the other hand, it is often desirable to keep the end thrust as low as possible, which requires a lower

[1] This subject has been discussed in a previous issue.

helix angle than the first consideration. The final answer is usually a compromise between these two factors.

Method of Production. The best method of production depends upon the accuracy of the cutting tools and machines actually available. If one had to choose between a Fellows machine which was in good condition and a hobbing machine which was not, or between an accurate Fellows cutter and an unground hob, the Fellows machine would be unquestionably the better. On the other hand, if these conditions were reversed, the hobbing machine would be the better. If the conditions were equal as regards the two types of machines, there would be but little choice between them, except when the gear was so large that the high fillet produced on the Fellows machine interfered with the tip of the gear tooth.

Choice of Pitch. The finer pitch is intrinsically smoother running because, first, the tooth profile departs less from the pitch circle and thus is less sensitive, and second, because with the same helix angle, more teeth will be in contact across the face, and thus average any spacing errors present among a larger number. Also, the finer pitch is more efficient. This is due to the fact that the tooth profile departs less from the pitch circle, so that the average sliding is materially reduced. This has shown up very prominently in some of the tests made here recently.

In the two examples given in the question, the second would probably be the quieter in operation, not because of tooth-profile contact or method of cutting but because of the finer pitch and higher helix angle. (Earle Buckingham, Associate Professor, Engineering Standards and Measurements, Massachusetts Intitute of Technology.)

Oil and Gas Power

Light-Weight Oil Engines

OG-6 What are the outstanding problems to be overcome in the development of an efficient light-weight, high-speed oil engine?

These problems may be broadly classified as follows:

(*a*) *Psychological.* Ourselves, our mechanics, our backers, and the prospective buyer expect these engines to run like an automobile motor. They are quite as noisy, though, as aircraft engines, by reason of the generally large clearances required. We shall have to accustom ourselves and others who really need these engines to this condition.

Physical. The greatest physical limitation lies in the fact that the spray is an orifice through which fuel must be injected within a certain crank angle. Variations of economy are rather marked at pressures below 4000 lb. per sq. in., while pumps are difficult to maintain at pressures exceeding 6000 lb. It will be understood that if an engine is to be flexible, having, let us say, a 10 to 1 speed range, a fixed orifice is impractical, for the pressure variations would be enormous. (H. F. Shepherd, Chief Engineer, Diesel Dept., Bessemer Gas Engine Co., Grove City, Pa.)

(*b*) First, one of the outstanding problems is to get even distribution of fuel between the cylinders at all loads; second, good regulation, which is influenced by the above; third, a smokeless exhaust, that is, as perfect combustion as with the low-speed type; fourth, satisfactory light-load and no-load operation. (W. W. Schettler, Chief Engineer, The Foos Gas Engine Company, Springfield, O.)

The Oil Engine in the Automotive Field[2]

OG-7 What appears to be the future of the oil engine in the automotive field, especially for large buses?

The present type of Diesel engine is, of course, much too heavy to be suitable for automotive work, and it will take, it is estimated, considerable time and much development work to get such engines sufficiently reliable to give satisfaction in the hands of the ordinary persons now driving automobiles. Further, considerable development work will be necessary to reach the degree of flexibility now attainable in the modern gasoline engine and to which the public is so accustomed. It is possible that it will reach the automotive field sooner through electrical transmission than direct drive. (W. W. Schettler, Chief Engineer, Foos Gas Engine Company, Springfield, O.)

[2] This subject has been discussed in a previous issue.

Railroad

Back Pressure in Locomotive Cylinders

R-12 What has been done to reduce or eliminate back pressure in the cylinders of a locomotive? Apparently the back pressure is one of the prime reasons for the relatively low efficiency of the steam locomotive. The back-pressure problem has been solved in power-plant operation; why can't it be done on the steam locomotive?

Elimination of back pressure in a locomotive to an extent comparable with that found in stationary practice necessitates the use of a condenser. Full condensing operation has been attempted in railway practice in turbine and turbo-electric locomotives, some of which have been built in recent years. The condensation of all of the exhaust steam in a locomotive necessitates providing the required draft through the boiler in some other way than by the use of the exhaust jet. This is a problem which the stationary-power-plant man is not worried about, inasmuch as nature provides the necessary drafts through the medium of a chimney. The widespread introduction of feedwater heaters and exhaust-steam injectors on locomotives has, to a noticeable degree, reduced the back pressure on the pistons of the engine, and it may be said that these devices, to some extent, are condensers, and by reducing the back pressure improve the performance of the locomotive in addition to reclaiming heat from a portion of the exhaust steam. (Unsigned contribution.)

Miscellaneous

Definitions of "Stress" and "Strain"[2]

M-9 At a recent meeting of Committee E-1 of the American Society for Testing Materials the definitions of terms relating to methods of testing given on page 1109 of Part I of the Proceedings of 1924 were passed for adoption as standard, subject to the approval of Committee E-8. These definitions involve defining "stress," where used without a qualifying term, as meaning unit value, and similarly as it concerns "strain." This usage is contrary to the inquirer's understanding of general engineering practice where "stress" usually indicates the total quantity, and unit stress or stress per unit of area the unit quantity. An examination of available literature and thorough discussion in this department should prove valuable, and may prevent misunderstandings after the standard has been adopted.

Engineering terminology when applied to the determination of testing and standardizing must necessarily itself be thoroughly standardized. From the standpoint of testing materials the words "stress" and "strain" always have had a very definite meaning, requiring at no time any qualifying term when used in the strictly correct meaning.

When a solid body is acted upon by external forces two effects are produced: (1) the body is deformed, resulting in *strain*, and (2) internal resisting forces are developed offsetting the external forces; this is *stress*.

Hence the two definitions: Strain is the amount of deformation produced in a unit of length. Stress is the amount of internal force produced per unit of area.

The writer believes that it should be permissible to use the five types of stress, i.e., tensile, etc., as qualifying terms. "Unit stress" appears ambiguous. "Total stress" is also unnecessary and should at no time be used to indicate load. (John C. Somers, Production Engineer, Baltimore, Md.)

Questions to Which Answers Are Solicited

Crankless Oil Engines

OG-9 With what success has the crankless type of oil engine been used? Give operating results and maintenance figures, length of time in continuous successful operation, and any additional information tending to establish the position of the engine in the power field.

Malleable- and Cast-Iron Screwed Fittings

STANDARDS for malleable-iron screwed fittings designed for a maximum working saturated-steam pressure of 150 lb. per sq. in. and cast-iron screwed fittings for 125 and 250 lb. per sq. in. have just been completed. This work was done by the Sectional Committee on the Standardization of Pipe Flanges and Flanged Fittings, organized under the procedure of the American Engineering Standards Committee. The Sponsors for this project are the Heating Piping Contractors' National Association, the Manufacturers' Standardization Society of Valve and Fittings Industry, and The American Society of Mechanical Engineers.

These three standards are now passing through the final stages necessary to make them "Tentative American Standards." Copies in page-proof form are now available and may be procured by addressing C. B. LePage, Assistant Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y.

The introductory notes to each set of tables of standard dimensions are practically identical, so we are reproducing below the Notes of the Cast-Iron Screwed Fittings standards.

Introductory Notes—Standards for 125- and 250-Lb. Cast-Iron Screwed Fittings

1 Pressure Ratings. These standards shall be known as the "American 125- and 250-Lb. Cast-Iron Screwed Fitting Standards," said pressure designation being the recommended maximum working saturated steam rating.

2 Size. The "size" of the fittings scheduled in the following tables is identified by the corresponding "nominal pipe size." For pipe 14 inches and larger, the corresponding O.D. of the pipe is given.

In the case of reducing tees and crosses, the size of the largest run opening shall be given first, followed by the size of the opening at the opposite end of the run. Where the fitting is a tee, the size of the outlet is given next. Where the fitting is a cross, the largest opening of outlet is the third dimension given followed by the opening opposite. The straight-line sketches [Fig. 1—not reproduced here] illustrate how the reducing fittings are read.

3 Marking. Each fitting of the "American 125-Lb. Cast-Iron Screwed Fitting Standard" shall be marked for identification with the maker's name or symbol.

Each fitting of the "American 250-Lb. Cast-Iron Screwed Fitting Standard" shall be marked for identification by means of

(*a*) Maker's name or symbol: and

(*b*) The numerals "250."

4 Metal Thickness. It is recognized that some variations are absolutely unavoidable in the making of patterns and castings. In order to define what may be considered a reasonable degree of accuracy in body thickness measurements of these fittings, the following Inspection Limits shall be allowed:

TABLE 1 DIMENSIONS OF CAST-IRON SCREWED ELBOWS, 45-DEG. ELBOWS, TEES, AND CROSSES FOR 125-LB. STEAM PRESSURE
(STRAIGHT SIZES)

Nominal pipe size	A Center to end elbows, tees, and crosses	C Center to end 45-deg. elbows	B Length of thread, min.	E Width of band, min.	F Inside diameter of fitting Min.	F Inside diameter of fitting Max.	G Metal thickness, Min.	H Outside diameter of band, min.
1/4	0.81	0.73	0.32	0.38	0.540	0.584	0.110	0.93
3/8	0.95	0.80	0.36	0.44	0.675	0.719	0.120	1.12
1/2	1.12	0.88	0.43	0.50	0.840	0.897	0.130	1.34
3/4	1.31	0.98	0.50	0.56	1.050	1.107	0.155	1.63
1	1.50	1.12	0.58	0.62	1.315	1.385	0.170	1.95
1 1/4	1.75	1.29	0.67	0.69	1.660	1.730	0.185	2.39
1 1/2	1.94	1.43	0.70	0.75	1.900	1.970	0.200	2.68
2	2.25	1.68	0.75	0.84	2.375	2.445	0.220	3.28
2 1/2	2.70	1.95	0.92	0.94	2.875	2.975	0.240	3.86
3	3.08	2.17	0.98	1.00	3.500	3.600	0.260	4.62
3 1/2	3.42	2.39	1.03	1.06	4.000	4.100	0.280	5.20
4	3.79	2.61	1.08	1.12	4.500	4.600	0.310	5.79
5	4.50	3.05	1.18	1.18	5.563	5.663	0.380	7.05
6	5.13	3.46	1.28	1.28	6.625	6.725	0.430	8.28
8	6.56	4.28	1.47	1.47	8.625	8.725	0.550	10.63
10	8.08	5.16	1.68	1.68	10.750	10.850	0.690	13.12
12	9.50	5.97	1.88	1.88	12.750	12.850	0.800	15.47
14O.D.	10.40	....	2.00	2.00	14.000	14.100	0.880	16.94
16O.D.	11.82	....	2.20	2.20	16.000	16.100	1.000	19.30

All dimensions given in inches.
Dimensions for reducing elbows and reducing tees are given in Table 2 and Table 3, respectively.

Body-thickness measurements taken on any fittings at points diametrically opposite shall, when added together and divided by two, equal or exceed the minimum metal thicknesses set forth in these Standards.

Body thicknesses at no point shall be more than 10 per cent below the minimum metal thicknesses set forth in these Standards.

5 Threading. American Standard Pipe Threads shall be used in threading fittings, and variations in tapping and dying shall be limited to one turn either way from the standard size as determined by the working gages prescribed by the "American Standard Pipe Thread" (No. 3–1919) or its latest revision.

All female threads shall be countersunk a distance not less than one-half the pitch of the thread and at an angle of 45 degrees with the axis of the thread, for the purpose of easier entrance in making a joint and for protection of the thread.

The length of threads specified in all tables shall be measured to include the countersink or chamfer.

6 Ribs. The addition of ribs or lugs shall not be prohibited on any screwed fittings.

7 Fitting Dimensions. Tables of "center to end" dimensions are given for both straight and reducing fittings.

The dimensions in the tables of reducing fittings are for use only when making patterns for the specific reducing fitting in question and do not apply when a larger-size pattern is bushed to make the reducing fitting wanted.

It is recognized that some variations are absolutely unavoidable in the making of patterns and castings. In order to define what

(*Continued on page 1038*)

TABLE 4 DIMENSIONS OF CAST-IRON SCREWED ELBOWS, 45-DEG. ELBOWS, TEES, AND CROSSES FOR 250-LB. STEAM-PRESSURE
(STRAIGHT SIZES)

Nominal pipe size	A Center to end, elbows, tees, and crosses	C Center to end, 45-deg. elbows	B Length of thread, min.	E Width of band, min.	F Inside diameter of fitting Min.	F Inside diameter of fitting Max.	G Metal thickness, min.	H Outside diameter of band, min.
1/4	0.94	0.81	0.43	0.49	0.540	0.584	0.18	1.17
3/8	1.06	0.88	0.47	0.55	0.675	0.719	0.18	1.36
1/2	1.25	1.00	0.57	0.60	0.840	0.897	0.20	1.59
3/4	1.44	1.13	0.64	0.68	1.050	1.107	0.23	1.88
1	1.63	1.31	0.75	0.76	1.315	1.385	0.28	2.24
1 1/4	1.94	1.50	0.84	0.88	1.660	1.730	0.33	2.73
1 1/2	2.13	1.69	0.87	0.97	1.900	1.970	0.35	3.07
2	2.50	2.00	1.00	1.12	2.375	2.445	0.39	3.74
2 1/2	2.94	2.25	1.17	1.30	2.875	2.975	0.43	4.60
3	3.38	2.50	1.23	1.40	3.500	3.600	0.48	5.36
3 1/2	3.75	2.63	1.28	1.49	4.000	4.100	0.52	5.98
4	4.13	2.81	1.33	1.57	4.500	4.600	0.56	6.61
5	4.88	3.19	1.43	1.74	5.563	5.663	0.66	7.92
6	5.63	3.50	1.53	1.91	6.625	6.725	0.74	9.24
8	7.00	4.31	1.72	2.24	8.625	8.725	0.90	11.73
10	8.63	5.19	1.93	2.58	10.750	10.850	1.08	14.37
12	10.00	6.00	2.13	2.91	12.750	12.850	1.24	16.84
14 O.D.	11.00	....	2.25	3.10	14.000	14.100	1.33	18.40
16 O.D.	12.50	....	2.45	3.45	16.000	16.100	1.50	20.88

All dimensions given in inches.
The 250-lb. standard covers only the straight sizes of fittings.

TABLE 1 DIMENSIONS OF MALLEABLE-IRON SCREWED ELBOWS, TEES, CROSSES, AND 45-DEG. ELBOWS FOR 150-LB. STEAM PRESSURE
(STRAIGHT SIZES)

Nominal pipe size	A Center to end, elbows, tees, and crosses	C Center to end, 45-deg. elbows	B Length of thread, min.	E Width of band, min.	F Inside diameter of fitting Min.	F Inside diameter of fitting Max.	G Metal thickness, min.	H Outside Diameter of band, min.
1/8	0.69	0.68	0.25	0.200	0.405	0.435	0.090	0.693
1/4	0.81	0.73	0.32	0.215	0.540	0.584	0.095	0.844
3/8	0.95	0.80	0.36	0.230	0.675	0.719	0.100	1.015
1/2	1.12	0.88	0.43	0.249	0.840	0.897	0.105	1.197
3/4	1.31	0.98	0.50	0.273	1.050	1.107	0.120	1.458
1	1.50	1.12	0.58	0.302	1.315	1.385	0.134	1.771
1 1/4	1.75	1.29	0.67	0.341	1.660	1.730	0.145	2.153
1 1/2	1.94	1.43	0.70	0.368	1.900	1.970	0.155	2.427
2	2.25	1.68	0.75	0.422	2.375	2.445	0.173	2.963
2 1/2	2.70	1.95	0.92	0.478	2.875	2.975	0.210	3.589
3	3.08	2.17	0.98	0.548	3.500	3.600	0.231	4.285
3 1/2	3.42	2.39	1.03	0.604	4.000	4.100	0.248	4.843
4	3.79	2.61	1.08	0.661	4.500	4.600	0.265	5.401
5	4.50	3.05	1.18	0.780	5.563	5.663	0.300	6.583
6	5.13	3.46	1.28	0.900	6.625	6.725	0.336	7.767
8	....	....	1.47	1.125	8.625	8.725	0.403	9.995

All dimensions given in inches.
Dimensions for reducing elbows and reducing crosses are given in Table 2, and dimensions for reducing tees in Table 3.

Engineering and Industrial Standardization

Graphic Presentation

IN THIS section of the July, 1927 issue of MECHANICAL ENGINEERING the committee organization for work on standards for graphic presentation was presented. It is now possible to print for criticism and comment a tentative draft of the first report of Sub-Committee No. 2 on Terminology. The second report will deal with the Terminology of Graphic Presentation.

The personnel of this sub-committee is as follows:

Mortimer B. Lane, editor, *Survey of Current Business*, Bureau of the Census, Washington, D. C., member at large.

Addison Boren, treasurer, Yale and Towne Manufacturing Company, Stamford, Conn., representing the National Association of Cost Accountants.

William C. Clark, economist, S. W. Straus and Company, New York, N. Y., representing the American Management Association.

F. W. Donahoe, statistician, Pittsburgh, Pa., member at large.

R. S. Kellogg, secretary, News Print Service Bureau, New York, N. Y., representing the American Trade Association Executives.

Lester C. Morrow, managing editor, *American Machinist*, New York, N. Y., representing the National Conference of Business Paper Editors.

TENTATIVE REPORT ON GRAPHIC TERMINOLOGY OF BUSINESS STATISTICS

Inquiries and Projects. Statistics on inquiries are now being gathered by several organizations and, in view of their increasing usefulness, it seemed well to the sub-committee to add definitions of these items. The sub-committee suggests the following definition for projects:

> Projects are clearly indicated requirements, sufficiently definite to justify sales efforts.

Projects may be reported by those who planned them or by manufacturers or contractors securing orders. Projects, therefore, are somewhat different from inquiries in that they contain no duplications. The statistician of the F. W. Dodge Corporation, who has been collecting statistics on building projects for a long time, suggests that this definition might be more concrete if expressed as a program of intended purchases, as he feels that many concerns would take a salesman's call as enough to justify sales effort. The sub-committee suggests that inquiries be defined as follows:

> Inquiries are formal requests for figures or other information in connection with projects. Duplication may be avoided by identifying the sources of all such inquiries.

It was felt that firms reporting inquiries should make every effort to exclude those emanating from curiosity seekers or students, and, if inquiries were hooked up with projects, this might be done. Inquiries should not be confused with bids, as the inquiry often comes well in advance of the bid. In fact, the bid is often only a few days in advance of the award of contract which would be counted as an order.

New Orders. The sub-committee recommends the following definition of new orders:

> New orders represent all data indicating orders, reservations, bookings, contracts, and commitments that are definite as to quantity during the period under review.

The sub-committee felt it was important that orders should not include indefinite authorizations for goods until definite quantities had been given, as indefinite reservations are merely options on future production. On the other hand, any order that is for a definite quantity, even if the time of shipment is not definite, should be included, and it was felt that all orders should be so definite that the parties could be held under contract. On orders calling for more or less than a certain amount of goods, the exact amount named should be included in the order, and if when the final shipping instructions are given it appears that the actual quantities will be larger, the additional amount should then be added to the new orders, or, if smaller, they should be added to cancellations. Any additions to old orders should, of course, be put in the new orders for the period. Goods for consumption in further manufacture in one's own plant should also be treated as orders, even if simultaneous with their production or shipment, so that order figures will balance with the production and shipment items. Following the report of the American Trade Association Executives, the sub-committee would discourage the use of the word "sales" as indicating orders, reservations, bookings, contracts, or commitments. Accounting practices definitely designate sales as applying to items delivered and billed. The sales forces improperly think of an order as a sale.

Cancellations. The sub-committee suggests the following definition of the term "cancellation."

> Cancellations include all items taken off the order record for the period under review in any manner except by shipment.

The intention of this definition is to provide not only for cancellation of orders, whether originally booked previous to the period or during the period, but also to allow for writing off unfilled balances and to adjust differences between orders for more or less than a certain amount of the actual shipments.

Net New Orders. The sub-committee suggests the following definition for net new orders:

> Net new orders represent the difference for the period of orders minus cancellations. Net new orders may also be calculated by adding to the unfilled orders at the end of the period the shipments during the period and subtracting therefrom the unfilled orders at the beginning of the period.

Unfilled Orders. The sub-committee suggests the following definition of unfilled orders:

> Unfilled orders are the sum of all unfilled balances of orders on record after deduction of cancellations at the close of the period.

Shipments. The sub-committee suggests the following definitions for shipments:

> Shipments represent the disposition of the commodity by any form of delivery to or for customers or related establishments or departments functioning as customers.

The sub-committee felt that the term "sales" might be used in connection with deliveries made over the counter or otherwise in retail-store practice, but in no case should this term be used to indicate orders. Returned goods should be deducted from shipments.

Transshipments. The sub-committee suggests the following definition for transshipments:

> Transshipments are deliveries to related establishments or departments functioning as customers and should not be reported as shipments for purposes of totals for an industry or trade, although they may properly be shipments for an individual establishment.

The word "related" as used in this definition applies to similar establishments within an industry buying the products of competitors for resale, in order to fill out their own lines. Goods sold on consignment would be included in transshipments, since they are not delivered into the ownership of the customer until sold.

Stocks. The sub-committee distinguished among three classes of stocks according to the condition of manufacture and suggests the following definitions of the term "stock:"

> Finished stock includes all finished products on hand at the close of the period ready for delivery to or for customers or related establishments or departments functioning as customers.
>
> Process stock includes materials on hand at the close of the period in which work has been started but not completed.
>
> Raw-material stock includes materials on hand at the close of the period upon which no work has been done by the industry to which it is raw mate-

rial. Such goods may, however, be finished products of another industry or department.

In accordance with the practice indicated under "shipments," consigned goods should be included under "finished stock" by the industry making the consignment until the goods are sold. It is believed that the above definition of finished stock will help to segregate stocks as between different industries or functions, in that manufacturers operating retail stores would not include their retail stocks in the data for manufacturers, since they had already been delivered to the department functioning as a consumer.

The sub-committee recognizes the tendency to compare stocks and unfilled orders to obtain a balance of one or the other. It therefore suggests the following definitions:

Free stock consists of the finished stock on hand, at the end of the period, of specific items, less the amount of such items as are applied on unfilled orders.

Uncovered orders consist of unfilled orders on record, at the end of the period, of specific items, less finished stocks applicable to such orders.

The sub-committee felt that without a breakdown of stocks and orders into specific items, such as grades, sizes, etc., the above data would not be indicative, since a mere balance showing the excess of stocks or unfilled orders would not show whether the unfilled orders could be filled from stocks on hand, owing to the various limitations as to sizes, grades, etc. The sub-committee is particularly desirous of finding a word more expressive then "uncovered." Other words suggested are "unprotected" and "unapplied."

Production. The sub-committee suggests the following definition of the term "production:"

Production consists of goods actually finished ready for shipment. It may be calculated by taking the sum of finished stocks at the end of the previous period plus shipments made during the period under review, minus finished stock on hand at the end of the period.

Through the calculation of production as shown above, the item of physical loss would be allowed for. The sub-committee feels that it is quite important that production include only goods that will be shipped out and not the total output, a large part of which might be rejected on inspection, broken in transit through the plant, spoiled, etc., before going into stock or being shipped.

Conclusion. The sub-committee wishes to point out that this report is tentative in nature, and that many improvements can undoubtedly be made therein. Furthermore, it might be desirable to cover additional items of business statistics, such as machinery activity, measures of value or price, working time, etc. The chairman was instructed to distribute this preliminary report, particularly to trade-association executives, for their criticism through the Secretary of the American Trade Association Executives.

Criticism and comment on these suggestions for standard definitions of important terms are solicited by the sub-committee, and our readers are urged to assist the forwarding of this project in this way. Letters should be addressed either to the chairman direct at the address given above or to C. B. LePage, Assistant Secretary, A.S.M.E., 29 West 39th Street, New York.

Tolerances and Allowances and Gages for Metal Fits[1]

THE importance of limit gages in quantity production as typified by the Tentative American Standard in Tolerances and Allowances and Gages for Metal Fits (B 4a-1925) is well exemplified by instances mentioned in the annual report of the Director of the Bureau of Standards, just off the press, where it is noted that the "production and inspection of the Springfield army rifle requires the use of 1263 gages; a machine gun, about 2200 gages; and one make of automobile, about 15,000 gages. The Ordnance Department of the War Department has under its charge in the various arsenals more than 500,000 gages, the replacement value of which is about $30,000,000."

The value of gages in the maintenance of dimensional standards of any kind during manufacture cannot be overestimated, particularly as respects quantity production of interchangeable parts.

[1] From the Sustaining Membership Bulletin of the American Engineering Standards Committee, 29 West 39th Street, New York, N. Y.

The following example based on the actual experience of a large plant will illustrate this point.

Manufacturers' cost of a well-known rifle, without the use of gages	$100.00
Manufacturers' cost of same rifle, using limit gages	24.00
Saving per rifle through the use of gages	$ 76.00

These figures show that more than three-quarters of the cost of the rifle is saved through minimizing the labor required in making the assembly, whereas interchangeability, an almost indispensable characteristic of modern small arms, would be quite impossible without the use of gages in production.

The extreme rapidity of accumulation of savings due to gages used in mass production is exemplified by the fact that in the manufacture of less than 4000 rifles the savings made would be sufficient to cover the cost of a complete set of gages necessary for assuring interchangeability of all components—amounting to nearly one-third of a million dollars.

The Springfield rifle as manufactured by the War Department is a remarkable instance of low cost of manufacture under mass-production conditions. Even on a basis of manufacture of only 30 rifles a day the cost of rifle is less than $28.00. The manufacturing cost of a custom-made rifle will lie between $80.00 and $100.00, not including any fancy ornamentation. Such rifles usually retail at $175.00 to $200.00. Even this price presupposes the use of a ready-manufactured breech mechanism, that is, a breech mechanism made in mass production, and if the makers of "hand-made rifles" had to produce the breech action as well as the remainder of the arm, the manufacturing cost might be practically prohibitive for such firearms. This range of price shows the extraordinary effect of modern manufacturing practices in reducing costs through the use of standards and the necessary gages. As to quality, we are advised on excellent authority that on the average the hand-made rifle referred to will neither be made of such fine materials nor with such good workmanship as will the low-cost mass-manufactured rifle.

On the other hand, it is somewhat surprising to note the large number of American factories carrying on a high-grade manufacture and yet taking advantage only to a very limited degree of the facility of production offered by limit-gaging systems. Such factories do an unnecessarily large amount of hand fitting and selection which could be reduced to routine at very much less cost by the general introduction of limit gaging, so as to make the process of assembly direct and straightforward without the delay, special skill, and frequent likelihood of error involved in the use of personal judgment unaided by measuring instruments.

The national standardizing body in Norway has recently published a draft for a standard system of fits. The system proposed is the unilateral system of tolerances, both the basic hole and the basic shaft system being given. However, the basic hole system is recommended as being preferable, and it is suggested that the basic shaft system might be done away with entirely, as the manufacture of mechanical power-transmission machinery in Norway is of little importance.

The proposed system is based on the principles of the German system of fits, although in a simplified form, the Norwegians evidently having no need of the elaborate German system, which contains 22 different grades of fit for a certain nominal diameter. The Norwegians have reduced this number to 12.

A.E.S.C. Year Book for 1927

THE 1927 edition of the A.E.S.C. Year Book is now available, and copies are being distributed to sustaining-members, technical societies, and trade associations coöperating with the American Engineering Standards Committee. Copies are also available to other interested groups and individuals; and it is suggested that sustaining members who wish copies of the Year Book to distribute to department heads, to the library, or to any other interested person in the company, address the office of the American Engineering Standards Committee, 29 West 39th Street, New York, N. Y., requesting the number of copies needed for the purpose

Revisions and Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision in the Rules in its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

During the past two years the Boiler Code Committee has received and acted upon a number of suggested revisions which have been approved for publication as addenda to the Code. These are published below, with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticisms and comment thereon from any one interested therein. Discussions should be mailed to C. W. Obert, Secretary to the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Boiler Code Committee for consideration.

After 30 days have elapsed following this publication, which will afford full opportunity for such criticism and comment upon the revisions as approved by the Committee, it is the intention of the Committee to present the modified rules as finally agreed upon to the Council of the Society for approval as an addition to the Boiler Construction Code. Upon approval by the Council, the revisions will be published in the form of addenda data sheets, distinctly colored pink, and offered for general distribution to those interested, and included in the mailings to subscribers to the Boiler Code interpretation data sheets.

For the convenience of the reader in studying the revisions, all added matter appears in small capitals, and all deleted matter in smaller type.

Revisions and Addenda

PAR. M–3. PRESENT PARAGRAPH TO BE MADE SECTION *a*. INSERT PAR. M–6, REVISED, AS SECTION *b*, WHICH READS AS FOLLOWS:

b Steam BOILER PARTS [generator elements] of not over 600 cu. in. in volume may be made of cast copper or bronze having a copper content of not less than 90 per cent and wall thickness of not less than $^1/_4$ in. Such STEAM BOILER PARTS [generators] shall be equipped with at least two brass wash-out plugs of not less than 1 in. iron-pipe size and shall be tested to a hydrostatic pressure of 600 lb. per sq. in.

PAR. M–4. REVISED:

M–4. The construction of miniature boilers, except where otherwise specified, shall conform to that required for power boilers. The factor of safety and method of computing the maximum allowable working pressure shall be the same as for power boilers. THE FLAT SURFACES OF BOILERS OR PRESSURE PARTS SHALL BE STAYED IN ACCORDANCE WITH PAR. P–204 OF SECTION I OF THE CODE.

PAR. M–6. REVISED:

M–6. THE TEMPERATURE OF THE HEATING ELEMENT FOR ELECTRICALLY HEATED STEAM BOILERS (CLOSED SYSTEM) SHALL BE SO CONTROLLED THAT IT WILL NOT EXCEED 1200 DEG. FAHR.

PAR. M–8. REVISED:

M–8. Tubes may be made of wrought iron, steel, drawn copper, or drawn brass. Fire tubes $1^1/_2$ in. and over shall have both ends substantially expanded into the tube sheet by rolling and beading. Fire tubes less than $1^1/_2$ in. shall be expanded and beaded, or expanded and welded. The gage of the tubes shall not be less than that specified for water-tube and fire-tube boilers in Pars. P–21 and P–22 of Section I of the Code.

TUBE HOLES SHALL BE DRILLED FULL SIZE FROM THE SOLID PLATE, OR THEY MAY BE PUNCHED AT LEAST $^1/_2$ IN. SMALLER IN DIAMETER THAN FULL SIZE, AND THEN DRILLED, REAMED OR FINISHED FULL SIZE WITH A ROTATING CUTTER.

THE SHARP EDGES OF TUBE HOLES SHALL BE TAKEN OFF ON BOTH SIDES OF THE PLATE WITH A FILE OR OTHER TOOL.

PAR. M–9. REVISED:

M–9. All rivet holes shall be drilled full size WITH PLATES, BUTT STRAPS AND HEADS BOLTED UP INTO POSITION, or they may be punched not to exceed $^1/_8$ in. less than full diameter and then drilled or reamed to full diameter WITH PLATES, BUTT STRAPS AND HEADS BOLTED UP INTO POSITION. THE FINISHED HOLES MUST BE TRUE, CLEAN, AND CONCENTRIC. AFTER DRILLING OR REAMING RIVET HOLES THE PLATES AND BUTT STRAPS OF LONGITUDINAL JOINTS SHALL BE SEPARATED, THE BURRS AND CHIPS REMOVED, THE PLATES AND BUTT STRAPS REASSEMBLED METAL TO METAL WITH BARREL PINS FITTING THE HOLES, AND WITH TACK BOLTS.

PAR. M–10. REVISED:

M–10. The calking edges of plates, butt straps and heads shall be beveled to an angle not sharper than 70 deg. to the plane of the plate, and as near thereto as practicable. Every portion of the UNFINISHED [sheared] surfaces of the calking edges OF PLATES, BUTT STRAPS AND HEADS shall be planed, milled, or chipped to a depth of not less than $^1/_8$ in. Calking shall be [so] done WITH A TOOL OF SUCH FORM that there is no danger of scoring or damaging the plate underneath the calking edge, or splitting the edge of the sheet.

PAR. M–12. REVISED:

M–12. Every miniature boiler shall be provided with at least one feed pump or other feeding device, except where it is connected to a water main carrying sufficient pressure to feed the boiler EXCEPT THAT WHEN THE STEAM GENERATOR IS OPERATED WITH NO EXTRACTION OF STEAM (CLOSED SYSTEM), NO FEEDING DEVICE IS REQUIRED, BUT IN LIEU THEREOF A SUITABLE CONNECTION OR OPENING SHALL BE PROVIDED TO FILL THE GENERATOR WHEN COLD. SUCH CONNECTION SHALL NOT BE LESS THAN $^1/_2$ IN. PIPE SIZE.

PAR. M–13. REVISED:

M–13. Each miniature boiler shall be fitted with feedwater and blow-off connections, which shall not be less than $^1/_2$ in. iron-pipe size UNLESS OPERATED ON A CLOSED SYSTEM AS PROVIDED IN PAR. M–12. The feed pipe shall be provided with a check valve and a stop valve. The feedwater may be delivered to the boiler through the blow-off connection, if desired. The blow-off shall be fitted with a valve or cock in direct connection with the lowest water space practicable.

PAR. M–14. REVISED:

M–14. Each miniature boiler for operation with a definite water level, shall be equipped with a [water] gage glass for determining the water level, EXCEPT THAT WHEN IT IS OPERATED WITH NO EXTRACTION OF STEAM (CLOSED SYSTEM), NOT LESS THAN TWO GAGE COCKS MAY BE USED INSTEAD OF A GAGE GLASS. The lowest permissible water level shall be at a point one-third of the height of the shell, except where the boiler is equipped with internal furnace, when it shall be not less than one-third of the length of the tubes above the top of the furnace. FOR CLOSED-SYSTEM BOILERS THE LOCATION OF THE LOWER GAGE COCK SHALL NOT BE LESS THAN $^1/_2$ IN. ABOVE THE HEATED SURFACE.

PAR. M–16. REVISED:

M–16. Each miniature boiler shall be equipped with a sealed spring-loaded pop safety valve, not less than $^1/_2$ in. in diameter, connected direct to the boiler, independent of any other connection. WHERE THERE IS NO EXTRACTION OF STEAM (CLOSED SYSTEM) A FRACTURING DISK SAFETY VALVE MAY BE USED IN ADDITION TO THE SPRING-LOADED POP SAFETY VALVE. The safety valve shall be plainly marked by the manufacturer with a name or an identifying trade-mark, the nominal diameter, the steam pressure at which it is set to blow, and A.S.M.E. Std. The minimum relieving capacity shall be determined on the basis of 3 lb. of steam per hour per square foot of boiler heating surface.

PAR. C–20. REVISED:

C–20. The most important rule in the safe operation of boilers is to keep water in the boiler and as constantly at the proper level as conditions will permit. Never depend entirely upon automatic alarms or feedwater regulators, no matter how effective or valuable these devices may SEEM TO be.

PAR. C–25. REVISE FIRST SENTENCE TO READ:

C–25. If any unusual or serious foaming occurs, close OR PARTLY CLOSE the steam outlet valve long enough to determine the true level of the water in the water glass.

PAR. C–30. REVISE FIRST SECTION TO READ:

C–30. When small leaks occur, locate their source and repair them as soon as the boiler can be removed from service. If a serious leak occurs, such as a leak along the longitudinal seam or near a flange of a drum head, shut down the boiler immediately by gradually reducing the steam pressure and have the boiler examined by an authorized inspector BEFORE RESTEAMING.

PAR. C–31. REVISED:

C–31. Many casualties have resulted from the practice of repairing boilers, pipe lines, and attachments under pressure; such practice should not be permitted except when officially authorized and under the supervision of a competent and responsible [person] ENGINEER.

PAR. C–33. REVISED:

C–33. Remove ashes frequently and do not permit the accumulation of any large amount of ashes in the ashpit, boiler flues, CONNECTIONS TO CHIMNEY, CONNECTIONS THROUGH ECONOMIZERS, or base of chimney. Do not pile ashes against the boiler front and when wetting down ashes, make sure that no water is thrown upon hot castings. To avoid being scalded, stand well back from hot ashes or refuse while spraying water on them. Do not leave ashes banked about blow-off pipes as a protection.

PAR. C–36. REVISED:

C–36. Allow the setting to cool SLIGHTLY [slowly, particularly if there is much sediment in the boiler. After the setting has been cooled] and WHEN there is no pressure on the boiler, open A [the] vent to prevent the formation of a vacuum, and empty the boiler. WHEN PRACTICABLE, EMPTY BOILER ONLY WHEN THE SETTING IS COOL SO AS NOT TO BAKE OR DRY SCALE ON TO TUBES AND HEATING SURFACES AND AVOID ANY TENDENCY TO CAUSE LEAKAGE AT SEAMS OR EXPANDED JOINTS. When it is not practicable to empty a boiler at atmospheric pressure, blow it down at as low a pressure as is consistent with operating conditions. When the boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves that are opened are on the boiler that is to be emptied. As soon as the boiler is emptied, close the blow-off valves, remove the manhole plates, and, when necessary, the covers of other openings.

PAR. C–40. REVISE FIRST SECTION TO READ:

C–40. Use hose with sufficient water pressure or hand tools, if necessary, to remove scale. Disconnect the blow-off line and run the water to waste, or when [practical] PRACTICABLE, provide a screen which can be inserted in the OPENINGS TO THE blow-off [hole] CONNECTION. Wash the tubes of horizontal-return tubular boilers from below as well as from above.

PAR. C–61. REVISE SIXTH SENTENCE OF THIS PARAGRAPH TO READ:

If the valve does not then pop, the boiler [or the part] to which the valve is attached shall be taken out of service and the safety valve cleaned or repaired.

PAR. C–64. REVISE FIRST SENTENCE OF THIS PARAGRAPH TO READ:

Do not allow the setting or adjustment of safety valves by any one but a competent AND AUTHORIZED person.

PAR. C–71. REVISED:

C–71. When making a hydrostatic test, remove the safety valves and blank the opening or clamp the valve disk securely to the seat. Also remove the water column floats, if necessary. Make sure that the safety valve is restored to working condition after the hydrostatic test has been made AND TEST THE SAFETY VALVE BEFORE THE BOILER IS AGAIN PLACED IN SERVICE.

PAR. C–78. REVISED:

C–78. Allow the setting to cool SLIGHTLY [slowly, particularly if there is much sediment in the boiler. After the setting has been cooled] and WHEN there is no pressure on the boiler, open A [the] vent to prevent the formation of a vacuum, and empty the boiler. WHEN PRACTICABLE, EMPTY BOILER ONLY WHEN THE SETTING IS COOL SO AS NOT TO BAKE OR DRY SCALE ON TO TUBES AND HEATING SURFACES AND AVOID ANY TENDENCY TO CAUSE LEAKAGE AT SEAMS OR EXPANDED JOINTS. When it is not practicable to empty a boiler at atmospheric pressure, blow it down at as low a pressure as is consistent with operating conditions. When the boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves that are opened are on the boiler that is to be emptied. As soon as the boiler is emptied, close the blow-off valves, remove the manhole plates, and, when necessary, the covers of other openings.

PAR. C–89. REVISED:

C–89. In the event of flareback or the snapping out of THE burners where oil or gas is used, shut off the fuel supply and thoroughly ventilate the boiler before resuming firing.

PAR. C–92. REVISED:

C–92. All power boilers should be given one internal INSPECTION and at least one, but preferably two external inspections per year by the state or municipal inspectors having jurisdiction, or by the inspectors of the insurance company carrying the risk. These inspectors are hereinafter termed "authorized inspectors."

PAR. C–94. REVISED:

C–94. A record of each inspection shall be kept in a uniform manner so that any change of condition can be definitely compared, especially with reference to thickness of scale, corrosion, EROSION, cracks, and other unusual conditions.

PAR. C–96. REVISED:

C–96. An external inspection by the authorized inspector shall comprehend the superficial examination of the boiler, its appurtenances and connections, and does not necessarily require that the boiler be off the line. It is a form of examination made primarily to check up THE care and management.

PAR. C–97. REVISED:

C–97. The internal inspection of the boiler SHALL INCLUDE THE EXAMINATION OF THE PREVIOUS BOILER REPAIR AND INSPECTOR RECORDS [shall be] AND a comprehensive and thorough examination in every detail OF THE BOILER ITSELF, embracing particularly the determination of the suitability of the boiler for the pressure carried, strength of its parts, possible deterioration in service, and advisability of its continuance under the pressure APPROVED [carried] previous to inspection.

PAR. C–100. REVISED:

C–100. The walls, baffles, tubes, and shell shall be thoroughly swept down and the ash and soot removed to give the plant inspector opportunity to closely examine ALL the parts [and to eliminate danger from hot contact.]

PAR. C–104. REVISE FIRST SECTION TO READ:

C–104. Use hose with sufficient water pressure or hand tools, if necessary, to remove scale. Disconnect the blow-off line and run the water to waste, or, when practicable, provide a screen which can be inserted in the OPENINGS TO THE blow-off [hole] CONNECTION. Wash the tubes of horizontal-return tubular boilers from below as well as from above.

PAR. C–107. REVISED:

C–107. The plant inspector shall examine the boiler for level, noting whether or not there has been any tendency to settlement especially the transverse level of the top tubes in horizontal return-

tubular boilers. He shall see that proper provision is made for expansion AND CONTRACTION OF THE BOILER AND THE SETTING.

PAR. C–111. REVISED:

C–111. The plant inspector shall note the proximity of overhead shafts or any machinery which might drop [down] on or strike the boiler in case of accident.

PAR. C–113. REVISE FIRST SECTION TO READ:

C–113. A careful examination shall be made of the safety valve, its connection to the boiler, its escape pipe, its [drip] DRAIN and supports. ALL OPENINGS SHOULD BE FREE AND CLEAR.

PAR. C–116. REVISED:

C–116. Before entering the shell or drum the plant inspector shall see that the blow-off AND SURFACE BLOW-OFF valve, the main AND AUXILIARY steam valves, feedwater valves, and ALL other valves ON CONNECTING PIPES are closed AND A [use some] reliable method of safeguarding THESE VALVES WHILE any one IS inside the boiler SHALL BE USED.

PAR. C–117. REVISED:

C–117. Careful examination of the interior of the boiler shall be made for cracks, BROKEN STAYS, pitting, corrosion, EROSION, scale, and thin places in the shell. The upper half of drums in the steam space shall be examined particularly for signs of grease and oil.

PAR. C–119. REVISED:

C–119. The [location] CONDITION of the feed [discharge] PIPE and [the condition] of the trough under it IF USED, shall be noted. Dry pipes shall be examined to see that their openings and perforations are free from deposits. All interior fittings shall be examined for loose connections.

PAR. C–123. REVISED:

C–123. Where soot blowers are used the inspector should examine them and also examine the boiler tubes for injury due to DISCHARGE FROM THE BLOWER NOZZLES [impingement of steam.]

PAR. C–128. REVISED:

C–128. An examination of the condition of the main header and its connections to the boiler shall be made to ascertain that it is properly supported, that due allowance is made for expansion AND CONTRACTION without throwing strains on the boiler, and that the non-return stop valves are in good working condition and so placed that there is no pocket in the connection to hold water unless it be properly drained.

PAR. C–129. REVISED:

C–129. The plant inspector shall note the position of the steam gage and gage cocks AND MAKE SURE THE WATER PIPE CONNECTING THE WATER COLUMNS DRAINS TOWARD THE BOILER. [Ascertain that the pipes leading to the water column and water glass are level and] Check the position of the water glass by leveling across the top row of tubes or from the position of the fusible plug.

PAR. C–156. REVISE FIRST SENTENCE TO READ:

Do not allow the setting or adjustment of safety valves by any one but a competent AND AUTHORIZED person.

PAR. C–166. REVISED:

C–166. When making a hydrostatic test of a boiler, remove the safety valves and blank the opening, or clamp the valve disks securely to the seats. Also remove the water-column floats if necessary. Make sure that the safety valve is placed in good working condition after the hydrostatic test has been made, AND TEST THE SAFETY VALVES BEFORE THE BOILER IS AGAIN PLACED IN SERVICE.

CENTER HEADING. REVISE CENTER HEADING TO READ: CONTROL OF [excessive] COMBUSTION.

PAR. C–171. REVISE SECOND SENTENCE TO READ:

[In general] In cutting in a boiler to a steam header already in service, the steam line between the boiler and the header is usually warmed up by [backfeed through the drip line or by] means of the by-pass valve, and the header valve then fully opened to allow the boiler to cut itself in automatically with the non-return valve.

PAR. C–172. REVISED:

C–172. Care shall be used that there is no SERIOUS weakening of the boiler structure due to fire cracks, abnormal DETERIORATION [crystallization] of parts, [and] OR other defects because of intensified combustion due to an increase in the rate of operation, increased stoker capacity, or change of fuel.

PAR. C–174. REVISE SECOND SENTENCE TO READ:

Gas pressure in the furnace shall be AVOIDED [minimized] as far as practicable, as pressure in the furnace forces hot gases out through the crevices in THE setting and tends to destroy it.

PAR. C–217. REVISE SECOND SECTION TO READ:

When kerosene is employed for cleaning the blades of steam turbines, provisions should be made TO PREVENT IT FROM GAINING ENTRY INTO THE FEEDWATER [for discharging the used portions direct into the sewer or other waste].

PAR. C–220. REVISED:

C–220. Where open heaters are used, [these] THEY should be well vented to the atmosphere for carrying off corrosive gases. A separator should be provided for removing any oils that may exist in the exhaust steam for heating the water. AN OVERFLOW FOR REMOVING ACCUMULATIONS OF IMPURITIES FROM THE TOP SURFACE OF THE WATER WITHIN THE HEATER and blow-down connections of ample size should be provided for discharging solid materials that may settle from the water.

PAR. C–228. REVISED:

C–228. GREATEST care SHOULD [shall] be used to prevent the entrance of oil ESPECIALLY THOSE CONTAINING ANIMAL OR VEGETABLE FATS into a boiler as it IS LIABLE TO [will] collect in clots on the heating surfaces, causing bagging or rupture.

PAR. C–233. REVISE LAST SENTENCE TO READ:

Removal of scale from the exterior of fire tubes by vibrating them with an internal cleaner or hammer must be practiced with caution as it may [cause] DAMAGE THE [a serious strain on] thin tubes.

PAR. C–243. REVISED:

C–243. Where pitting is experienced [the surface of] THE CAUSE SHOULD BE ASCERTAINED AND REMOVED. UNTIL THE CAUSE CAN BE REMOVED ALL OF THE CORRODED SURFACES should be cleaned TO THE METAL [carefully] and [the pits filled with zinc oxide paste or other] SOME protective coating APPLIED to check FURTHER corrosive action.

PAR. C–246. REVISE LAST SENTENCE TO READ:

For this alkalinity use 1.5 [1.2 lb.] OZ. of caustic soda per 100 lb. of water contained within the boiler.

PAR. C–249. REVISED:

C–249. Boilers in service may be exposed to external leaks of different kinds which tend to corrode the shell. The operator shall guard against leaky safety valves and steam mains which drop condensation on the boiler and cause external corrosion, especially where the water MAY run under THE protective coverings.

PAR. C–255. REVISE FIRST SENTENCE TO READ:

C–225. When a fire-tube boiler is to be out of service for a long period, the [exposed portion of] shell AND TUBE SURFACES THAT COME IN CONTACT WITH THE PRODUCTS OF COMBUSTION shall be given a coat of grease, red lead, black japan, or tar paint to prevent external corrosion.

PAR. C–268. REVISED:

C–268. All structures over boilers, whether they are part of the boiler installation or building structure, shall be inspected periodically to see that DETERIORATION [corrosion] does not occur, and shall be kept IN GOOD CONDITION [well painted] at all times.

PAR. C–271. REVISED:

C–271. The fastenings of all interior fittings such as braces, baffles, feed troughs, OR PIPES, gratings, zinc baskets OR PLATES, and dry pipes shall be maintained secure [and free from lost motion].

PAR. C–279. REVISE LAST SENTENCE TO READ:

No welding or patching shall be done except upon and in accordance with the advice of AN authorized boiler inspector.

PAR. C–280. REVISE LAST SENTENCE TO READ:

Isolated pits, not affecting the strength of THE material may be prevented from becoming serious by cleaning the pit carefully and electrically welding, or by APPLYING SOME FORM OF [filling in with zinc paint or other] protective coating.

PAR. C–288. REVISE FIRST SENTENCE TO READ:

C–288. Tubes in fire-tube boilers which have been rolled several times and still leak, may be WELDED AS SPECIFIED IN PAR. C–279 OR improved temporarily by rolling and beading the tube and then inserting a tight-fitting internal ferrule of boiler tube stock of a gage equivalent to that of the tube and of a length equal to 3 times the thickness of the tube sheet.

PAR. C–295. REVISED:

C–295. All boilers, with their auxiliaries and appurtenances shall be located, as far as practical, where they will be least liable to damage from external forces such as building failures, flywheel OR TURBINE explosions, flood, fire, or explosions from the storage of inflammable material, belt-transmission failure, and other possible disasters.

PAR. C–312. REVISE LAST SENTENCE TO READ:

Escape pipes should be supported so as to prevent any UNDUE strain upon the safety valve.

PAR. C–335. REVISED:

C–335. Pipe lines connected to boilers shall be installed with provision for expansion and contraction. Pipe lines shall be braced to prevent UNDUE strains on boiler or connecting pipe lines, and supports shall be of sufficient strength and designed to withstand strains set up by possible water hammer or vibration.

PAR. C–336. REVISE LAST SENTENCE TO READ:

Supports for piping shall not be attached to wooden or steel structures such as floor or roof beams, WHEN THEIR ALIGNMENT MAY BE SERIOUSLY AFFECTED BY DEFLECTIONS CAUSED BY CHANGES IN LOAD [where liable to be affected by changes in load].

PAR. C–337. REVISED:

C–337. When stacks are supported from structures directly above the boilers, or from the boilers themselves, SUITABLE PROVISIONS SHALL BE MADE [care shall be taken] TO PREVENT [all steelwork from] corrosion OF ALL STEELWORK caused by water at this location running down on the stack, or from the roof.

PAR. C–339. ADD THE FOLLOWING NEW PARAGRAPH:

C–339. PROPERLY GUARDED LADDERS, STAIRWAYS, PLATFORMS, AND RUNNING BOARDS SHOULD BE PROVIDED FOR ALL BOILERS AND THEIR ACCESSORIES WHERE NEEDED.

PAR. C–340. ADD THE FOLLOWING NEW PARAGRAPH:

C–340. GOOD LIGHTING SHOULD BE PROVIDED ALL ABOUT THE BOILERS ESPECIALLY ON TOP OF BOILERS FOR EMERGENCY USE—AND AMPLE EXTENSIONS FOR USE IN AND ABOUT THE BOILERS FROM TWO SOURCES IF PRACTICAL.

PAR. C–341. ADD THE FOLLOWING NEW PARAGRAPH:

C–341. NUMEROUS EXITS SHOULD BE PROVIDED FROM BOILER ROOMS, SINCE DERANGEMENT TO BOILERS AND THEIR ACCESSORIES IS ALWAYS LIABLE TO OCCUR.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 547, 551, and 553 to 556 as formulated at the meeting of June 24, 1927, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 547

Inquiry: a Is it permissible under the requirement of Par. P-186 of the Code to form corner joints between the shells and heads of power boilers by the use of fusion welding, where the shell is extended beyond the head and carries an angle or other structural shape riveted thereto on the inner side, so as to withstand the thrust on the head due to steam pressure?

b Is it permissible under the requirement of Par. P-186 of the Code to form the girth shell joints of firebox-type boilers having furnaces and water legs extending the full length of the shell, by fusion welding, when such joints are disposed half way between adjacent rows of staybolting and the head-to-head stresses on the shell are fully carried by through rods and tubes?

c Is it permissible under the requirement of Par. P-186 of the Code, in firebox-type boilers, to weld the corner joints of furnaces that are subject to compressive stresses when both head and side sheets are supported by rows of staybolts close to the corners?

Reply: a If the shell is cylindrical or in the case of firebox construction is retained by staybolting, it is the opinion of the Committee that the use of such a structural member so disposed as to oppose the thrust due to steam pressure and properly attached to the extended shell by riveting according to the rules for circumferential joints, will not conflict with the requirement of Par. P-186.

b It is the opinion of the Committee that while the through rods and tubes may perhaps be sufficient to withstand the calculated head-to-head stresses of such a firebox-type boiler, neither the longitudinal staying effect of the through rods nor the transverse reinforcement of the staybolting in the water legs will be sufficient to insure freedom of the girth joint from transverse tension stresses due to weight components or variations in temperature, and thus the construction proposed will not meet the Code requirement.

c It is the opinion of the Committee that while the staybolting will perhaps amply support the head and side sheets, their attachment by fusion welding at the corners will not meet the requirements of the Code, as the welds would not be free from bending and tension stresses due to both steam pressure and contraction and expansion.

CASE NO. 551

Inquiry: Will it be permissible to form a nozzle on a drum of diameter not less than 30 in., where the shell is 2 in. or more in thickness, by the use of a steel tube not exceeding 3 in. in diameter, which is rolled into a hole in the drum and into an outer flange? Attention is called to the fact that if a flanged nozzle were to be attached to a drum by riveting as required in Par. P-268 of the Code, the rivets would become so long that it would be difficult to make a tight and satisfactory joint, and also it is believed that the method of screwing a threaded pipe connection into the drum as provided for in Par. P-268 would be unsatisfactory on account of damage to the threads through corrosion or other means.

Reply: A revision of the requirement pertaining to nozzles in Par. P-268 is being considered which will modify the present mandatory requirement for the riveted attachment to shells or drums. It is the opinion of the Committee that the proposed construction is allowable under the conditions specified.

CASE NO. 553

Inquiry: What will be the proper location for the fusible plug of an h.r.t. boiler that is set with a slope to the rear so that the rear end is 1 or 2 in. lower than the front end? Par. A-21*a* speci-

fies the location as in the rear head not less than 2 in. above the upper row of tubes.

Reply: It is the opinion of the Committee that if the lowest visible part of the water gage glass is located on a level 2 in. above that of the fusible plug in the rear head, the requirement of Par. P-291 of the Code will be met.

CASE NO. 554

Inquiry: Is it the intent of Par. H-68 of the Code, wherein it is stipulated that the stamps shall not be covered by insulating or other material, that the term "other material" shall include painting? If the section of the boiler shell to which the stamping is applied is not painted it is found to corrode badly during shipping and erecting of the boiler.

Reply: It is the opinion of the Committee that the term "other material" was not intended to include a thin protective coating which does not obscure the easy reading of the stamping impressed upon the boiler.

CASE NO. 555

(In the hands of the Committee)

CASE NO. 556

(In the hands of the Committee)

St. Louis Organizes for Smoke Abatement

THE Citizens' Smoke Abatement League of St. Louis was organized in the spring of 1926 largely through the efforts of the St. Louis Section of the A.S.M.E., in coöperation with the Women's Smoke Abatement League, the Associated Engineering Societies of St. Louis, and the Smoke Abatement Committee of the Chamber of Commerce. Early in 1927 the league was incorporated, the governing body now being a Board of Directors consisting of twenty-eight members.

During the past year the major efforts were devoted to making a smoke survey of the St. Louis district to establish standard conditions by which progress in the future can be measured, and also to determine definitely what classes of plants are responsible for the smoke.

The engineers of the League made a fuel survey of the entire metropolitan district. Totals of the various kinds of fuel used were determined and these were in turn subdivided among the various classes of fuel users. The great bulk of the fuel used in St. Louis is bituminous coal, most of it coming from the Illinois fields. Approximately 93 per cent of all fuel used for heating is bituminous coal, due largely to the proximity of St. Louis to the vast coal fields of Illinois and the consequent low cost of soft coal. On account of the predominance of the low-volatile Illinois coals in the St. Louis fuel situation, the St. Louis smoke problem is probably the most difficult of any large city in America.

Another important phase of the survey was a soot-fall study, which was carried on during the heating season. Containers were distributed over the district and placed in twenty typical locations. The classifications included downtown business, railroad, industrial, brickyard, apartment house, residence and suburban districts. The material collected in these containers was filtered and weighed. The residue was then burned in a crucible and the loss in weight, representing combustible material, was reported as soot. The weight of the soot was then calculated in tons per square mile per annum, this being a standard figure used in making soot-fall studies elsewhere. The average soot fall for the city of St. Louis during the heating season of 1926–1927 was 870 tons per square mile per annum. This compares with about 250 tons in Pittsburgh and 600 tons in Memphis. In Chicago at present the soot fall is about 150 tons in residence districts and 450 tons in the downtown business district. Throughout the heating season smoke densities were observed on all the various classes of plants in the territory. These densities were obtained by making readings according to the standard Ringelmann-chart method. Readings were taken at different times of the day and also at different periods of the year. The highest smoke densities observed were from clay-products plants, which had an average density of 43 per cent. The next highest density was from large heating plants such as hotels and office buildings, where the density was 23 per cent. The average density of railroad smoke was 20 per cent, and of industrial plants, 16 per cent. The average smoke densities of all classes of plants were then combined with the amounts of fuel used by each class and the distribution of the total smoke thus established. The results show that industrial plants make 50 per cent of the smoke, heating plants 42 per cent, and railroads 8 per cent. The detailed distribution of smoke among the various classes of plants in St. Louis and the suburbs immediately adjoining it in St. Louis County is as follows:

	Per cent
Clay products plants	26
Industrial power plants	24
Apartments (6-family and up)	14
Office buildings, hotels, warehouses and large heating plants	12
Two- and four-family flats, stores, garages, and small heating plants	8
Railroads	8
Schools, hospitals, and institutions	4
Residences	4
	100

Taking what is called the entire metropolitan district, including East St. Louis, Granite City, Venice, and Madison, Illinois, the division of smoke is:

Industrial plants	63
Heating plants	26
Railroads	11
	100

The increased proportions of industrial and railroad smoke, when taking the east side of the district into consideration, is doubtless due to the fact that no smoke-abatement work has ever been done on the east side. Also the industrial plants and railroads on the east side use 90 per cent of all fuel used on that side of the river.

Before attempting smoke-abatement work on the heating plants on a large scale, experimental work was carried on in certain localities so that some idea could be obtained as to the value of such work. In several selected districts, instructors called on every fuel user in the district. These men explained the educational program of the League, gave firing instructions, and offered cooperation. Smoke densities were taken both before and after this patrol work was done. Very encouraging results were obtained. Reductions of smoke ranging from 40 per cent to 79 per cent were secured in a few days' time. The League proposes to carry out this work on a large scale during the coming season. The territory will be divided into districts and a man will be stationed permanently in each district. He will coöperate with all fuel users, give firing instructions and keep a strict watch for the bad smokers.

After working on a comparatively small scale for several months, the Citizens' Smoke Abatement League decided to carry out a comprehensive program. Knowing that the St. Louis smoke problem could not be solved in a few months, or in one year, it was decided to initiate a three-year program. An intensive financial campaign was carried on and approximately $253,000.00 was raised by popular subscription to carry on the work of the League for three years. So far as we know, this is the largest amount ever raised in any American city to carry out a smoke-abatement program.

The League is working on an engineering program, based largely on the recommendations of O. P. Hood, Chief Mechanical Engineer of the U. S. Bureau of Mines. No prosecutions will be attempted. The League in the course of its studies has found that 80 to 90 per cent of the people will coöperate and believes that best results can be accomplished by a campaign of education and cooperation.

MECHANICAL ENGINEERING

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Management and Machine Tools

WITHIN that domain controlled by American business men, overproduction is a fallacy of the past. Equipping for production, manufacturing and marketing have been coördinated, and any conditions existing or anticipated in the ultimate function are quickly reflected down the line. The temptations that exist in vast markets for manufactured goods have seldom led to blindly increasing production for the sake of quantity alone. Even greater quantity production for the sake of lower cost is now approached with discretion—with an eye on the limit of volume that can be sold at a stated price, and, therefore, must be produced at a stated cost.

Matters of cost, manufacturing methods, production quantities and equipment are today directing the attention of management primarily toward machinery and machine tools, for in the present age machinery is the factor of primary influence in manufacturing success. Machine tools of the modern type are especially interesting because of the rapid developments in metal-working industries through recent years, and modern tools have advanced in type beyond the secondary position and are now virtually manufacturing machinery, turning out those mechanical units for household use and individual service with which we have all become familiar in the last few years.

The considerable list of machine tools of various models and types offering individually widely different ranges of adaptabilty and refinement both as to quality and quantity of production, presents a considerable problem in choice of equipment for specific manufacturing conditions. With a market for the product demanding a scale of manufacture that we have learned to call mass production, there is little difficulty in justifying the maximum refinements in manufacturing methods and equipment which result in maximum economy. With a limit in volume, however, such as is placed on some products, the point of maximum economy may fall considerably short of the maximum refinements for mass production, and it is a wise manager who knows just how far to carry the refinements in his particular case with methods and equipment and where to stop in order to obtain the greatest return for his efforts. The equipment factor is therefore where management can express its keenest judgment and ability.

On the other hand, the builders of machine tools have an intimate interest in these relative conditions. They will find markets worth developing in other than the mass-production field, and should be in position to offer tools economically suitable for various stages of production quantity. Any builder who has specialized for years on one class of machining operations is obviously best fitted to build the mechanical requirements of performance into units of equipment particularly adapted to the conditions presented in various quantities. But to do this effectively, he must have a clear understanding of the items in manufacturing expense which will be affected by his equipment, and which, in a large measure, will determine the attitude of the prospect toward its purchase. Investment expenses, tooling and equipping for the specific job, service, maintenance, indirect and direct labor are all included as factors of production cost. In addition he must keep in mind the life of the job as now running, the tendency toward frequent change, the flexibility required, and the condition of the market in which the products of his machine are sold, whether stable, expanding, or contracting.

In attempting to meet the conditions of lower manufacturing cost, however, he will inadvertently contribute through other less obvious channels to the general benefit of business conditions and to the envied position of American business. The releasing of man power from ardous labor for better work and for higher arts in industry and commerce is an addendum to the overcoming of labor shortage or the mere squeezing of the labor-cost factor out of production cost. The shortening of process time of manufacture from raw state to finished product is worth while on the cost basis alone, and more perfect performance of equipment may reduce the capital tied up in inventories and in work in process. But in this way a contribution is also made to the more active circulation of money and credit, to the conservation of raw materials, and to the ability of the manufacturer to more promptly comply with the demands of the market. He has a definite hand in the release of frozen capital and the balancing of inventories and production, in reducing the cost of living or raising the standard, in conserving health, and in spreading greater pleasure and happiness throughout the world.

But the present attitude of a purchaser toward a machine-tool proposition is that it must refund the investment out of savings in manufacturing cost within a period of two to four years at the outside. Sometimes it must even be refunded from a saving effected in direct labor cost alone, and the genius of the machine-tool builder has so far made it possible for him to comply with that requirement.

E. P. BULLARD, JR.[1]

Combating the Smoke Nuisance

THE demand for smoke abatement in the United States usually comes from civic organizations and particularly from the women's clubs. Many prominent citizens are enthusiastic about smoke abatement from a civic standpoint but often know little about the real problem. Frequently the first two remedies suggested are the universal use of smokeless fuels and the passage of a drastic ordinance. As a rule, such measures do not stop very much smoke.

It is difficult to induce people to purchase any but the cheaper fuels, and attempts to disturb the present economic situation with respect to fuels are usually unwise. The problem is to learn how to burn the fuels available as smokelessly as possible. Smoke abatement is an engineering problem.

The history of smoke abatement in the United States reveals the fact that drastic legislation does not usually accomplish any real results. Much more can be accomplished by education and coöperation.

When a business man receives notice that he is to be prosecuted for violation of the smoke ordinance, the matter is immediately turned over to his attorney and taken out of the engineer's hands. The case then becomes involved in legal technicalities which usually result in interminable continuances in court. Very often 12 to 18 months pass by before the case is brought to trial. During this

[1] President, The Bullard Machine Tool Co., Bridgeport, Conn. Mem. A.S.M.E.

time smoke violations continue, and usually the man is antagonistic and will make no effort to improve conditions. Experience has shown that a policy of education will accomplish quicker and better results. It has been demonstrated in St. Louis that seventy-five to ninety per cent of the people will coöperate in an educational campaign.

One of the principal reasons for failure in many smoke campaigns is that people do not realize the magnitude of the job. Smoke abatement is a major municipal problem and must be considered on the same basis as maintenance of streets, keeping the water pure, removing city waste, or guarding the moral atmosphere. Large appropriations are necessary and the work must be continuous.

One of the best means of eliminating smoke is to watch the smoker and to let him know that he is constantly being watched; never-ceasing effort on a comprehensive scale is the price of success in a smoke-abatement campaign. The technical side of the smoke problem, especially in industrial and larger heating plants, is well known to fuel and combustion engineers, but the public must be brought to realize that this is an engineering problem. In addition to the technical phase, there is a tremendous human problem. No matter how well designed or well built the plant, a great deal depends upon its proper operation. The human factor always plays a large part, and a successful smoke-abatement engineer must be well versed in tact and diplomacy.

The tremendous losses and damage due to the smoke nuisance are appalling. The Department of Commerce estimates that the annual cost of smoke to the American public is at least five hundred million dollars. Undoubtedly the waste of fuel alone is in excess of fifty million tons every year. The items in our annual smoke bill cover damage to buildings and merchandise, extra cost of cleaning and decorating, etc. This does not take into account the effect of smoke on health, which, according to prominent physicians, is detrimental.

Any one interested in this subject will be amply repaid by attending the First National Fuels Meeting, to be held in St. Louis in October. One whole day will be devoted to the various phases of the smoke problem. The Technical Division of the Citizens' Smoke Abatement League of St. Louis is carrying on some original research work on the firing of domestic furnaces. The results of this work, which are quite interesting, will be presented at the Fuels Meeting.

Smoke abatement is a mechanical engineer's job and should be of especial interest to the members of our Society. Engineers must not forget that they have a special obligation to the public. Smoke abatement is one of the special problems which have arisen with the congestion of humanity in our modern cities. It is one of those problems which the engineer, and only the engineer, can cope with. Here is a field for great public service on the part of the Local Sections of The American Society of Mechanical Engineers. They should take the initiative and leadership in cities where the smoke problem is paramount.

A New Era in Fuels

IT HAS been reported in the papers, and the report has been confirmed officially by the New York office of the Standard Oil Company of New Jersey, that Mr. W. C. Teagle, president of the latter company, has signed a contract with the German "Chemical Trust" under the terms of which the American company has acquired an interest in the German organization's methods for the production of liquid fuel from coal, known generally as the Bergius Process.

In engineering, as elsewhere, official recognition plays an important role. Just as in the days of old, no man, no matter how valorous, became a knight until he had received the accolade from one to whom it had already been given, so in industry, invention often does not gain full recognition until it has been taken up by some concern of undisputed standing. It was thus with the Bell telephone, which received its greatest impetus through being adopted by the then already great Western Union Company. The entrance of the Standard Oil Company of New Jersey into the synthetic-fuel field, however, signifies much more than simply an endorsement of the German process.

In the first place, it means that synthetic liquid fuels from coal have arrived. The Rockefeller interests have always been averse to destructive competition from the outside. An illustration of this tendency may be observed in New York City where these interests control the Consolidated Gas Company, which in turn controls the New York Edison Company. There has, therefore, been no such destructive competition in the metropolis between electric and gas lighting was often the case elsewhere in days gone by. The Standard Oil Company of New Jersey is one of the largest manufacturers of gasoline in the world, and it is both significant and encouraging to learn that it is to promote the introduction of another fuel which may take the place of gasoline when the large deposits of natural oil are exhausted.

Whether or not these deposits are actually likely to be exhausted has been a question on which considerable difference of opinion has been expressed, some claiming that there is oil enough in sight to last perhaps less than a generation, while others believe that new methods of discovery will open up an undetermined wealth of liquid fuel underground. Further, huge supplies of oil are available in the form of shale in the western states.

The fact that the Standard Oil Company of New Jersey has already become interested in liquid fuel from coal would indicate at least that those best informed on the subject appear to believe that the day when gasoline from oil will rise in price to a point where liquid fuel from coal will have a competitive chance, may not be as far afield as some think.

The development of the Bergius process is of interest in another way. There are several other processes by means of which certain amounts of liquid fuel can be obtained from coal. Most of these processes cannot become commercial, however, unless all of their by-products can be sold at a reasonable price, and unfortunately there is no market for some of them if produced on such a vast scale as the general application of the processes would require. It is claimed, however, that the Bergius process does yield by-products which can be directly or after further treatment sold at a price which would make the cost of the gasoline somewhere around thirty cents a gallon, a cost at which synthetic fuel can already compete with imported fuel in Europe, but not yet with native fuel in the United States.

To the mechanical engineer the development of synthetic fuel manufactured by the Bergius process is of interest as it will lead to a large production of stills, hydrogen gas separators, cryogenic apparatus, etc. It may also demand a thorough redesign of the modern explosion-type internal-combustion engine. In this there is nothing radically new. As a matter of fact, the automobile engine has already gone through a process of evolution due to changes in fuel. When the industry came into being, a very highly volatile gasoline was available as a waste product of kerosene manufacture. This was very fortunate, because the early designers of such engines would have had to travel a much harder road to success if they had not had such a convenient fuel, what with their lack of knowledge of design and the unsatisfactory systems of ignition then available.

The end of this high-grade fuel supply was in sight for at least two years before the beginning of the World War. Accordingly the industry started to experiment with cracking on a commercial scale, and in the meantime simply diluted true gasoline with the next lower fractions. At first this caused much trouble because of dilution of the lubricating oil, but later the difficulties were gradually overcome by the use of such devices as the hot-spot manifold, etc.

The experience with high-compression airplane engines during the war led to the development of so-called detonation dopes, permitting the use of such motors, and the present year is the first one in which there has been an attempt to put such motors on automobiles for general use. We do not refer to supercharging, as this development has not been hitherto connected with changes in fuel. We might, however, mention that coal products such as benzol have been already extensively used as motor fuels, and have even shown some superiority to gasoline in their non-pinking properties. The significance of the recent commercial developments in connection with the Bergius process lies, therefore, not in the application of a new principle, but in the prospects of its application on a vast commercial scale.

Alexander Crombie Humphreys

As the September issue of MECHANICAL ENGINEERING is being released for printing, word has been received of the death of Dr. Alexander Crombie Humphreys, on August 14, at his home in Morristown, N. J.

Dr. Humphreys, eminent gas engineer and past-president of The American Society of Mechanical Engineers, until his retirement in July of this year, had been president of Stevens Institute of Technology since 1902.

An account of Dr. Humphreys' professional career will appear in the October issue.

Rapid Changes

ONE of the significant features of industry today is the great rapidity with which changes take place. The steamship was developed to the practical point in the very beginning of the 19th century and yet it was not until the early 80's that the tonnage of steam vessels built exceeded that of sailing vessels. There are many similar instances in the past of apparently antiquated methods of working which held their ground for a long time in the face of competition of more modern methods and presumably more efficient methods.

It is not necessary to discuss why this was possible. It is significant, however, that the present tempo of the industry has been accelerated to such an extent that it becomes more and more difficult for obsolete methods to survive. Whether it is because of the availability of greater amounts of capital which permit the quick reconstruction of old plants and the installation of new ones, or whether it is due to the high cost of labor which makes every saving in this direction count, or, as some claim, to the changed psychology of people who are no more afraid of new things because of their novelty, the fact remains that changes do take place with what would appear to be an amazing rapidity. The horse has been practically driven off the city streets by the automobile in 25 years, and on the farms it is rapidly being displaced by tractors. Within the last five years we have seen in this country the development of the motor bus as of a new powerful form of transportation, which in some places is already throwing into the discard old-established trolley lines and branch railroads.

Again, within only a few years a well-established industry manufacturing wooden boxes for shipping encountered a strong competition by the fiber box, the manufacture of the latter having developed into a large industry in a few years.

A still more interesting instance of such a mushroom growth is represented by the radio business, which has amounted to several hundred million dollars, worth of sets bought by the public in about four years, with the end not yet in sight.

Industrially, nothing seems to be stable in this shifting world of ours. Certain natural combinations have made of the arid deserts of Chile a source of supply of nitrates for the whole world, but within less than 15 years an artificial nitrate industry has been created, and now in England authoritative voices are already stating that within a few years England will completely cease to import natural nitrates and will cover all of its requirements—agricultural, industrial, and military—by artificial products.

About the time of the war there was a shortage of hides, due to the fact that in addition to normal demands, such as made by shoe, harness, and trunk manufacturers, there appeared a huge demand for leather for automobile upholstery. For a while it looked as if there would not be enough cattle to provide leather, and in fact methods were developed of splitting the hides so as to spread each one over several times its original area. Then came the production of artificial leather, with the result that perhaps the time is not far off when the problem may be to find any kind of use for genuine hide and leather. In fact, it is already a problem to sell all the leather available.

For years, the cold of winter was the only source of ice. Then artificial ice made in huge special plants gradually displaced natural stored ice. But about three years ago the small household refrigerator was developed to the point where it was sufficiently reliable in operation to be placed in the hands of the general public, and since that time an enormous industry has grown up. A generation ago the household-refrigerator industry would not have grown to its present size perhaps in 25 years.

Wherever we look we find huge industries growing up in an amazingly short time. Twelve months ago the continuous rolling of steel sheet was considered to be in the experimental stage, as only one company was doing it and that one said as little about it as possible. Today enough plants have been built or are building to produce some 15 tons of continously rolled sheets per minute.

In England and Germany where the price of oil products is high, several processes have been developed for the production of synthetic fuels for automobiles, and these have attained substantial proportions in only two years.

This rapidity of change carries with it two big lessons. One is to the manufacturer of established products that what is successful today may not be equally successful 24 months from now, and that every manufacturer must look keenly for changes occurring not only in his own industry but in industries generally. The second lesson is to the engineer. It has been said that the world will find a way to the door of the man who makes the best mouse trap. The world is looking today for new developments and has plenty of capital and willingness both to back the introduction of new methods and to buy the new products made thereby. Herein lies an opportunity for the engineer such as the world has never seen before.

Economies Resulting from Standardization[2]

JAMES H. RAND, JR., in his book "Assuring Business Profits," cites an interesting case of saving both to manufacturer and consumer through standardization. A certain type of filing cabinet had been made in two styles, one with a lock and one without, depending upon the needs of the individual consumer; the ones with the lock costing $2.70 each, plus some labor charge, over those without. It was found upon careful investigation that if locks were put on all cabinets, the simplification of manufacture and merchandising practices and the reduction of inventories made a saving more than enough to cover the cost of the locks, so that it was actually cheaper to make all the cabinets with locks than it was to make part with and part without. Obviously, the purchaser who receives a cabinet with a lock and has no use for it is under no disadvantage.

Mr. Gerard Swope, president of the General Electric Company in announcing a further reduction in the price of Mazda lamps, which is the eighth since 1920, points out that the "reductions . . . . have been made possible primarily by better manufacturing methods and by standardization and simplification of lamp types." The price trend in standardized products in mass production is well illustrated by the fact that these lamps are now 44 per cent below 1914 prices, whereas general commodity prices have increased 65 per cent since that year. It is evident that such products will have a steadily increasing market advantage over products which, due to lack of standards, increase in price proportionately to the cost-of-living increase, or at an even greater rate.

Malleable- and Cast-Iron Screwed Fittings

(*Continued from page 1028*)

may be considered a reasonable degree of accuracy in the "center to end" measurements of these fittings, a table of INSPECTION LIMITS which shall be all allowed is also given.

The tables omitted from this abstract have the following titles:

Malleable-Iron Fittings. Table 2, Dimensions of Elbows and Crosses (Reducing Sizes); Table 3, Dimensions of Tees (Reducing Sizes); Table 4, Dimensions of 45-Deg. Y-Branches (Straight Sizes); Table 5, Dimensions of Service or Street Tees and 90-Deg. and 45-Deg. Elbows (Straight Sizes); Table 6, Dimensions of Couplings (Straight and Reducing Sizes); Table 7, Dimensions of Caps; and Table 8, Dimensions of Close, Medium, and Open Patterns of Return Bends.

Cast-Iron Fittings. Table 2, Dimensions of Elbows (Reducing Sizes); and Table 3, Dimensions of Tees (Reducing Sizes).

[2] From Sustaining Membership Bulletin of the American Engineering Standards Committee, 29 West 39th Street, New York, N. Y.

Exhibit of Work-Holding Devices

THE New Haven Machine Tool Exhibition, held September 6–9, will devote part of its space to an exhibit unusual in character and purpose. The object of the management of the Exhibition has been from the start to make its display as educational in character as possible. With this in mind it has coöperated with the Museums of the Peaceful Arts in gathering a collection showing the evolution of the various types of work-holding devices and the principles of good jig and fixture design. It was felt that this would be applicable and helpful in a wide range of metal-working industries. After serving its purpose at the exhibition in New Haven, part of the collection will go to New York to join the permanent collection of the Museums of the Peaceful Arts, and can be seen there at the quarters of the Museums on the seventh floor of 24 West 40th Street.

At the time of this writing the exhibit has not been wholly completed but the make-up has been determined and the collection is well in hand. The general grouping is as follows:

1 Clamps, dogs, jacks, blocks, and wedges, and the evolution of T-head bolts and slots. These devices are undoubtedly the simplest and most primitive types of workholders. They are small, portable, and adaptable to location at almost any position with reference to the work, subject to the judgment of the machinist who uses them. Here one may see the direct application of three mechanical elements—the inclined plane, screw thread, and lever—in performing the sole function of work holding and nothing else. Developments in this group have been comparatively inconspicuous, with the exception of those that have recently taken place in the standardization of T-head bolts and slots, the most noteworthy being in the direction of increased strength, rigidity, and safety (safety setscrews on dogs).

2 Hand vises, machinists vises, machine-tool vises for drill press, planer, shaper, and milling machine. To illustrate the principles of good design covering locating stops, prevention of inserting work in the wrong position, dowel pins, equalizers, dirt grooves, etc.

3 Vises: hand, machinists', pipe-fitters', and other stationary types. Also machine-tool vises for drill press, planer, shaper, and milling machine. This class shows the evolution of the primitive clamp to the point at which it becomes a definite piece of machinery. As such, it loses much in portability and adaptability to a variety of jobs, but, through specialization of function and the development of different types, gains in strength, time-efficiency, and general usefulness in each distinct kind of job. Here also should be noted one of the most economical methods of holding for repetition work—specially formed jaws applied to standard vises.

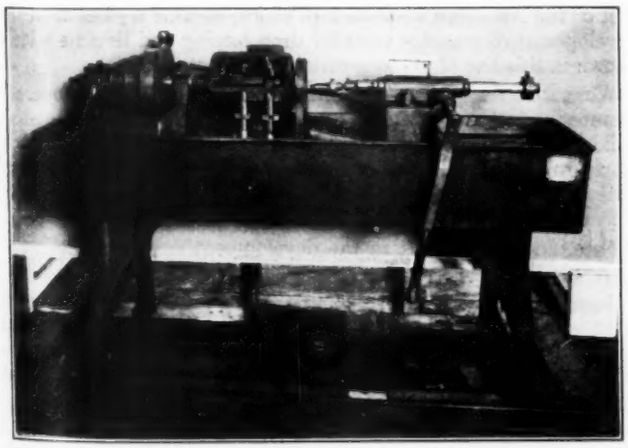

FIG. 1 EARLY DESIGN OF CHUCKING MACHINE

The design of such jaws is an art in itself, and this portion of the exhibit is arranged to illustrate such features as correct placing of locating stops, devices to prevent inserting work in the wrong position, proper use of dowel pins, equalizers, dirt grooves, etc.

4 Chucks: jaw types, universal, pneumatic, hydraulic, magnetic, etc. The chuck is a combination of faceplate and vise, and one of the interesting exhibits in this group is an early type of chuck which evidently partook of this dual nature in the mind of the man who built it. It consists of a hubbed disk (faceplate) to the face of which is attached one fixed block and one block adjustable toward or away from the other by means of two setscrews, thus introducing the principle of the vise with its one fixed and one moving jaw.

Another development in this field is the design of special chucks for interchangeable manufacture. One form which this has taken is the standard chuck with special jaws, corresponding to the standard vise with special jaws for quantity production on milling machines. Another form is the revolving fixture, an early example of which is shown in Fig. 1. This chucking machine was used for counter-

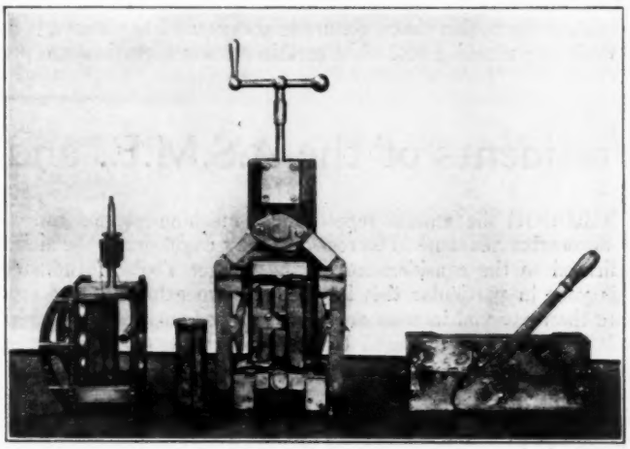

FIG. 2 TYPICAL JIGS AND FIXTURES

boring and reaming the hole in the end of shotgun receivers. As can readily be seen, the device for holding the receiver is essentially a fixture, designed exactly like a milling-machine fixture, but attached to the faceplate of a lathe instead. The cutting tool is guided by a bushing in the chuck or fixture, and receives floating support from the tailstock, which feeds it into the work by means of the long lever and a rack-and-pinion connection. Two additional cutters and a sample of the work are shown standing upright on the bed of the machine.

This machine was designed over fifty years ago, yet it is a remarkably sturdy little structure. It can undoubtedly turn out work today with all the accuracy required in high-grade firearms manufacture, although it is questionable whether it would stand up under modern cutting speeds and feeds.

5 Faceplates, centers, steady rests, follow rests and other lathe-type accessories. In this group the dead-center pulley for grinding machines is contrasted with the live-center pulley which was first used, being a natural copy of the live center in the headstock of the engine lathe. As is well known, accurate cylindrical grinding could not be guaranteed when the center as well as the driving dog rotated, but this difficulty has been completely obviated by so designing the driving pulley that the two functions of supporting and driving the work are completely separated.

6 Arbors, standard and special types showing a consistent development from the plain cylindrical design, applicable to work having only one size of hole, to various types of expanding mandrels, each size of which is useful over a more or less broad range.

7 Jigs, showing development of types and details to bring out such features as quick-acting screws and wrenches, knockout plugs for removing work, clearance for tools, chips, and burrs, 3-point support for work, 4-point support for jigs, handles, balancing, slip bushings, dirt grooves, clamping opposite supporting points to prevent springing, bushings inside of figure formed by feet of jig, evolution of drill bushings, various types of clamping devices, lids, latches, swing bolts, locating points and stops, indexing devices, etc.

8 Milling, planing, and chucking fixtures, to bring out prin-

ciples of proper-sized nuts and levers, avoidance of stacking, most advantageous position of work, avoidance of possibility of inserting work in wrong position, supporting points as far apart as possible, clamps to be operated from front of fixtures, proper provision for thrust, etc.

Fig. 2 shows a group of jigs and fixtures selected more or less at random from the collection in the New Haven exhibit, each of which brings out some interesting feature. At the left is a "rocking" jig. Here the drilling is performed first at one end (top in illustration) and then the other (bottom). The combination of jig and work is too heavy for the workman to lift it and turn it over with one hand, yet it is not heavy enough to justify a trunnion mounting with indexing pins. A neat compromise is struck by placing segmental shoes on one side of the frame, and a handle near the center of gravity. By simply giving the handle a twisting motion, the workman rocks the jig over from one position to the other, without having to lift it off the drill-press table.

One who is only casually interested in work-holding devices is apt to get the notion that a fixture is always used to clamp a piece of work to a machine tool while certain cutting operations are performed on it. Such however is far from true; in many instances it is desirable to hold certain parts of a machine in a fixture while they are being assembled, and in other cases a fixture may be designed simply to hold work while the latter is being gaged or tested. A good example of the latter is shown at the right of the illustration. This is a fixture for testing springs. The spring to be tested is V-shaped and is inserted at the point indicated by dotted lines, while the handle is against one of the stops; then the handle is pulled over to the other stop, and the pointer indicates the spring tension on the graduated scale, and shows whether it lies between the tolerated limits.

It is believed that a collection of this type has never been attempted; certainly no other is in existence at the present time. It should be of interest to tool makers and tool designers as an embodiment of a very important branch of shop practice, with which they may be familiar as it stands today, but of the development of which they probably have little knowledge. It will also appeal to machine-tool men in general as showing the evolution of a class of accessories without which the machine tool could not function in large-scale interchangeable production.

Presidents of the A.S.M.E. and "The Master Tools of Industry"

THROUGH the annual repetition of machine-tool exhibitions, September has come to be recognized by engineers as the month dedicated to the consideration of the Master Tools of Industry. This year in particular this is true, for two exhibitions of even more than national interest are being devoted entirely to machine tools, while a third is going to feature such exhibits along with other industrial equipment and material.

In addition to introducing to those immediately interested all of the worth-while new things in the machine-tool field, these exhibitions can accomplish at least two more missions of great benefit to the industry and to the world in general. One of these accomplishments will be the explosion of the myth that the machine-tool industry was, is, and always will be a sort of "war baby."

This myth has been accepted not only by the "man in the street" but also by many engineers who are not close to the practical side of production. It rests upon the fact that wars have stimulated the building of machine tools to an abnormal degree. As a matter of fact, the first standard machine tools were developed and built by firearms manufacturers for the interchangeable manufacture of army rifles, but the sword was never beaten into a plowshare any more effectively than have these basic tools been converted to the great achievements of peacetime production.

Nor have wars of recent years resulted in many outstanding developments of machine tools. They have generally only resulted in a feverish production of great quantities of existing tools to meet the emergency. For instance, it may be said that 1914 model tools were still being built in quantities in 1918. The second great myth that the exhibitions can explode is therefore the one that machine tools reached a peak development as well as a peak production during the World War. What actually happened was that in 1918 and 1919 the unwholesome production of 1914 machine tools came to an end, and there began an era of sane production based upon intensive development. It is safe to say that since 1920 there have been *more*, and more *vital*, improvements in machine-tool design than in any seven-year period since the industry came into being. Wartime machine tools began to be "shown up" as obsolete by new models exhibited as far back as 1920. Succeeding exhibitions have made this condition increasingly evident because trends in design have altered both the appearance and character of familiar production machines. 1927 exhibitions will demonstrate conclusively the remarkable increased output and reliability represented by the new tools.

While some members of the Society have expressed the feeling that machine-shop practice has always received its full measure of attention in Society affairs, others more closely associated with this subject have felt that machine tools and machine-shop practice have not received attention enough. Both parties to this question may be surprised and enlightened by what the following survey of the forty-six presidents of the A.S.M.E. reveals. Of these forty-six presidents at least ten have played active roles in the progress and development of the machine-tool industry.

John E. Sweet was, at the prime of his life, a prolific inventor of precision machine tools, and was one of the early and ardent advocates of accuracy in the machine shop;

Coleman Sellers was a scientist who applied his powers to the metal-working field and was one of the leading machine-tool builders of his time;

Oberlin Smith was a pioneer in the development of machine tools for the stamping and forming of sheet metal, and became one of the most successful manufacturers of these machines and their dies;

Charles E. Billings, after serving his apprenticeship in one of the first of the American machine-tool shops, became a pioneer in the development of machine tools for drop forging and became widely known in this line of manufacturing;

Worcester R. Warner and Ambrose Swasey, both Honorary Members of the A.S.M.E., learned their trade as machine-tool builders in one of America's pioneer plants, and during their nearly fifty years of partnership have come to be one of the best-known firms of machine-tool builders in the world;

Frederick W. Taylor reduced the art of cutting metals to a science, and by his part in the development and introduction of high-speed steel completely revolutionized machine-shop practice;

James Hartness is one of the outstanding improvers of the turret lathe, and by his inventive genius, coupled with his able industrial leadership, he has within less than forty years brought about the transformation of a Vermont village into one of the outstanding machine-tool centers of the world;

Fred J. Miller is one of the deans in the machine-tool editorial field, and has for many years been widely recognized as an authority upon management in the metal-working industries;

Dexter S. Kimball has long been an accurate and interesting interpreter of machine-tool history, and has brought about a much-needed realization of the importance of machine tools to civilization through his creation of the famous slogan—"The Master Tools of Industry."

With these, as well as numerous other strong figures, holding high places in the A.S.M.E., it is evident that machine tools and machine-shop practice have received no more than their just share of attention. The Society is well justified in promoting the success of outstanding machine-tool exhibitions and in encouraging technical sessions devoted to machine-shop practice. Members, on the other hand, should be inspired not only to attend the exhibitions but also to do their share in contributing worthwhile papers and discussions to machine-shop practice sessions sponsored by the Society.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

ACTIVATED SLUDGE PROCESS. By Arthur J. Martin. Macdonald & Evans, London, 1927. Cloth, 7 × 10 in., 415 pp., illus., diagrams, tables, 30 s.

In this book we have a comprehensive survey of this modern process of sewage purification, accompanied by a useful bibliography of the voluminous periodical literature. The author provides a useful summary of the various opinions on disputed points, describes the methods that have been successful at different places, and supplies cost data. The work brings together the facts that have been established and the results that have been achieved, in a convenient form.

AIRPORTS AND AIRWAYS. By Donald Duke. Ronald Press Co., New York, 1927. (Ronald Aeronautic Library.) Cloth, 6 × 9 in., 178 pp., illus., diagrams, maps, tables, $5.

This book will be of service to municipalities and commercial organizations interested in the establishment and operation of airports. The author discusses the location and construction of airports, the equipment needed, and the maintenance of the plant. The organization of airways is also discussed and much useful advice, based on personal experience, is given.

ALUMINUM BRONZE POWDER AND ALUMINUM PAINT. By Junius David Edwards. Chemical Catalog Co., New York, 1927. Cloth, 6 × 9 in., 104 pp., illus., tables, $3.

Describes the manufacture of aluminum bronze powder, its properties, and its industrial uses. The greater part of the book is devoted to aluminum paint, and the author discusses in detail the composition and special properties of this paint, as well as its application to various materials.

BUSINESS ANNALS. By Willard Long Thorp. National Bureau of Economic Research, Inc., New York, N. Y. Cloth, 6 × 9 in., 380 pp. $4.

Tells, in descriptive form, the vicissitudes of economic fortune in seventeen countries for periods ranging from thirty-six to one hundred and thirty-six years. Presents briefly, for each country, the year by year fluctuations in manufacturing, construction, employment, trade, prices, speculation, financial operations and agriculture, as well as important non-economic events that supposedly influence economic activity. The book throws valuable light upon business cycles and is a useful condensed record of happenings in the recent past.

CALCULUS OF VARIATIONS. By A. R. Forsyth. University Press, Cambridge, England; Macmillan Co., New York, 1927. Cloth, 8 × 11 in., 656 pp., 50 s.

Dr. Forsyth's treatise on the calculus of variations is the first in English for many years. While it makes no pretensions to an encyclopedic range, it covers the subject more fully than any of its predecessors and gives a systematic exposition of it by a uniform composite process. The book is based upon the work of Moigno and Lindelöf, and of Weierstrass, but much of its material is novel, and a large part is due to independent work by the author.

DIESEL MASCHINEN, III. *Zeitschrift V.D.I.* Special Number of V.D.I. Verlag, Berlin, 1927. Paper, 8 × 12 in., 99 pp., illus., diagrams, 4.50 r.m.

This book contains the papers upon Diesel-engine construction which appeared in the *Zeitschrift des Vereines deutscher Ingenieure* during 1926, and which are here reprinted in convenient form for reference. The twelve papers are the work of leading experts; taken collectively, they form a good survey of the present position of the Diesel-engine industry.

ELEKTRISCHE BAHNEN. By A. Schwaiger. Walter de Gruyter & Co., Berlin and Leipzig, 1927. Cloth, 4 × 6 in., 116 pp., illus., diagrams, 1.50 r.m.

A brief account of the present situation in railroad electrification, especially full with respect to conditions in Germany. Electric locomotives are discussed.

ELEKTRISCHE FÖRDERMASCHINEN. By W. Philippi. Second edition. S. Hirzel, Leipzig, 1927. (Elektrizität in industriellen betrieben, bd. 6.) Paper, 7 × 10 in., 310 pp., illus., diagrams, 20 mk.

A practical treatise on the construction and operation of electric mine hoists, intended for the mining engineer. The author describes the mechanical and electrical machinery and the control and safety devices, and discusses the advantages of electric hoists, giving special attention to their safety and economy. A number of typical installations are described and a list of references is given.

ERGEBNISSE DER AERODYNAMISCHEN VERSUCHSANSTALT ZU GÖTTINGEN, Lieferung 1–3; edited by L. Prandtl and A. Betz. R. Oldenbourg, Munich and Berlin, 1923–1927. 3 pts., paper, 8 × 11 in., illus., diagrams, tables. Pt. 1, 8 mk; pt. 2, 6 mk; pt. 3, 14.50 mk.

The first three numbers of a publication to be issued at irregular intervals by the Aerodynamical Experiment Station at Göttingen. The publication is intended to make the most important results of the experimental work at the Institute more conveniently available to engineers and manufacturers than hitherto, when they have only appeared in summaries in periodicals.

The first number contains a description of the Institute and of the directions which its investigations had taken before 1920, accompanied by the results. It also includes an introduction into the study of the resistance of the air, in which the basic laws of aerodynamics are explained. The later numbers, issued in 1923 and 1926, contain, in addition to theoretical studies, reports of many investigations of interest not only to aeronautical engineers but also to students of wind resistance in connection with railroads, bridges, and other fields.

FESTIGKEITSUNTERSUCHUNGEN ZUR NORMUNG DER STAHL-ALUMINIUM-SEILE. By Verband Deutscher Elektrotechniker. V.D.I. Verlag, Berlin, 1927. (Forschungsarbeiten auf dem gebiete des ingenieurwesens heft 293.) Paper, 8 × 11 in., 12 pp., tables, 0.80 r.m.

The Commission on Overhead Lines of the Association of German Electrical Engineers presents this report on the strength of aluminum-steel cables. It contains the results of tests of the elasticity and tensile strength of these cables and of the coefficients of thermal expansion and the strains resulting therefrom. The results are tabulated and their use in practical calculations is illustrated.

FOREMANSHIP. By Glenn L. Gardiner. A. W. Shaw Company, Chicago and New York, 1927. Cloth, 6 × 9 in., 680 pp., $6.

The work of a former director of foremanship training for the Oakland Motor Car Co., this book presents the principles and prac-

tices which lead to success as a foreman. The author discusses the place of the foreman in management, analyzes the qualifications necessary, and describes his job and his duties. Methods for developing foremen are given, and there are sections on practical methods of procedure. The final section presents some of the more important principles of industrial economics.

FOUR-FIGURE TABLES. By C. Godfrey and A. W. Siddons. University Press, Cambridge, England; Macmillan Co., New York, 1927. Cloth, 6 × 9 in., $0.80.

A convenient collection of the usual mathematical tables of logarithms, natural and logarithmic trigonometrical functions, squares, square roots, reciprocals, and radians. The tables are clearly printed on good paper and are well adapted to the needs of students.

FUNDAMENTALS OF ELECTRICAL DESIGN. By A. D. Moore. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 353 pp., illus., diagrams, tables, $4.

This course in design is not intended to teach the student how to design electrical machinery. Real knowledge and skill in that art can only be acquired, in the author's opinion, through actual experience in professional work. Instead of attempting the impossible, Professor Moore offers a course which directs attention to a mastery of certain fundamental subjects which are basic to much professional electrical design, among which are the electromagnetic system, fields and field mapping, attraction, and the thermal problems of heat storage, heat flow, heat radiation, heat dissipation, and rise in temperature. In the latter part of the book the application of this knowledge is illustrated by applying it to the problems of direct-current machinery.

DIE GEWINDE: Namen- und Sachverzeichnis. By G. Berndt. Julius Springer, Berlin, 1927. Paper, 6 × 9 in., 16 pp., 1 r.m.

Users of Dr. Berndt's valuable collection of data upon the manufacture and measurement of screw threads will be greatly helped by this name and subject index to his work. The index covers the original book and the supplement issued in 1926.

HEROES OF AVIATION. By Laurence La Tourette Driggs. New and revised edition. Little, Brown & Co., Boston, 1927. Cloth, 5 × 8 in. 346 pp., portraits, $2.

A vividly written account of the part played by the aviator in the World War, especially the exploits of the more famous airmen in the various armies on the western front. Tabulations of the victories accredited to the strongest air fighters of each nation are included, and there is a roster of the Americans killed while flying. First published in 1918; now revised.

HYDRAULICS. By Ernest W. Schoder and Francis M. Dawson. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 371 pp., illus., diagrams, tables, $3.50.

This work does not attempt to treat exhaustively any phase of hydraulics nor to offer a short course on any one of the professional fields of hydraulic engineering. It aims rather to be a basic course in the hydraulics of engineering, which may serve both as an introduction to more specialized studies and as a text and reference book on every-day problems.

The treatment has four stages: first, description of the physical phenomena; second, development of the fundamental laws into useful formulas; third, presentation of examples showing good form in the analysis and good methods in the solutions of problems; fourth, typical problems drawn from practical cases. The course is long enough for usual college requirements.

THE IRON INDUSTRY IN PROSPERITY AND DEPRESSION. By Homer Bews Vanderblue and William Leonard Crum. A. W. Shaw Co., Chicago and New York, 1927. Cloth, 8 × 11 in., 193 pp., diagrams, tables, $7.50.

Presents the results of investigations designed to apply to a single industry certain statistical methods for the analysis of recorded data, and undertaken in part with the aim of developing a method of forecasting conditions in that industry. The topics considered are prices and production, the regional production of pig iron, and the forecasting of conditions in the industry. The book does not attempt to be an exhaustive analysis of all the material bearing on the iron and steel industry, but it gives a sufficiently full view of the problem to be helpful in understanding conditions in it, and also to point the way to similar analyses of other industries.

KRÜMMUNGEN ZYLINDRISCHER KESSELTEILE WÄHREND DES BETRIEBES. By P. Rönne. V. D. I. Verlag, Berlin, 1927. (Forschungsarbeiten auf dem gebiete des ingenieurwesens, heft 292.) Paper, 8 × 11 in., 43 pp., diagrams, 5 r.m.

Gives the results of an investigation of the strains caused in cylindrical boilers by differences of temperature within the plates and between the plates. The causes of these strains, their size, the failures that they cause and the prevention of such failures, are discussed. The changes of shape caused by differences in temperature were measured for boilers of various types, and formulas derived for calculating the resulting strains. The study shows how differences of temperature may cause failures, and what steps must be taken in construction and operation to prevent them.

LEGAL ASPECTS OF ZONING. By Newman F. Baker. University of Chicago Press, Chicago, 1927. Cloth, 5 × 8 in., 182 pp., $2.50.

Mr. Baker discusses the attitude of courts and lawmakers toward some of the more important questions that arise in connection with city planning. The extent to which the law takes cognizance of municipal aesthetics, legislation respecting zoning and the problem of the metropolitan area or region are considered, special attention being paid to court decisions upon contested points. Of interest to engineers as well as lawyers.

DER SCHIFFSMASCHINENBAU. Vol. 2. By G. Bauer. R. Oldenbourg, Munich and Berlin, 1927. Paper, 8 × 11 in., 630 pp., illus., diagrams, tables, 54 r.m.

The second volume of Dr. Bauer's great treatise on marine engines is devoted to steam turbines and reducing gear. The theory of the turbine is discussed first, after which the design of the turbine is treated at length. Turbine construction is then taken up, followed by sections on reducing gear, on turbine operation, and on the installation of turbines in ships. A suggestive section on land turbines concludes the book, except for 168 pages of appendixes, in which many matters in the first volume are brought up to date. A third volume, on internal-combustion engines, is promised.

The work is a valuable record of European practice in design and construction, of interest to every marine-engine builder.

SIR ISAAC NEWTON: A brief account of his life and work. By S. Brodetsky. Methuen & Co., London, 1927. Cloth, 5 × 8 in., 161 pp., portrait, map, diagrams, 5 s.

An attempt to present the main features of Newton's life and his chief contributions to knowledge in a manner that will be understood by a reader who possesses a very moderate grounding in the elements of science. The author successfully tells all that the average inquirer will wish to know of Newton and of his influence on scientific thought.

STREAM GAGING. By William Andrew Liddell. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 238 pp., illus., diagrams, tables, $3.

This volume presents briefly the theories of stream flow which bear on stream gaging, considers practical methods for applying these theories to the measurement of flow, examines the characteristics of the various measuring devices, and outlines methods for analyzing stream-flow data. The book provides a ready working knowledge of the general nature of stream flow and of practical methods for determining the rate of discharge.

UNTERSUCHUNG VON KRAFTWAGENKUPPLUNGEN, by E. vom Ende; and VERSUCHE MIT RUTSCHKUPPLUNGEN, by G. Weber. (Berlin. Technische Hochschule. Versuchsfeld für Maschinenelemente, Heft 6.) R. Oldenbourg, Munich and Berlin, 1927. Paper, 8 × 11 in., 48 pp., diagrams, 5 r.m.

This pamphlet gives the results of two investigations of automobile clutches carried out at the Berlin Technical High School. The first investigation is a comparative test of a cone and a disk clutch, built for the same load. The second investigation is a comparative study of the frictional properties of leather, fiber cloth and cast iron against cast iron, under the conditions of automobile operation.